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COMMUNICATIONS SUPPORT FOR FLIGHT DATA ENTRY AND PRINTOUT TERMINALS

NETWORK ANALYSIS CORPORATION
301 Tower Building
Vienna, VA 22180

AUGUST 1980
FINAL REPORT

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16. Abstract

The FDEP service, as it is to be upgraded under the FDIO program, was analyzed to determine the optimal communications support strategy. That analysis yielded the following conclusions:

- integration of FDEP into NADIN is more economical than independent operation of FDEP,
- provision of local switching for FDEP messages in the NADIN concentrators should prove economical as more services are absorbed by NADIN, and
- procurement of FDIO equipment that would not be used when FDEP is integrated into NADIN should be avoided unless the timely upgrading of FDEP would be otherwise jeopardized.

The analysis also produced detailed designs for local access FDEP circuits and identified specific enhancements required for NADIN if FDEP is to be absorbed.

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METRIC CONVERSION FACTORS

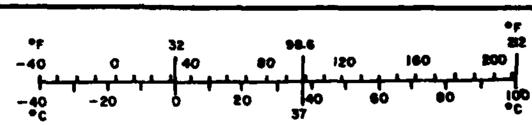
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The National Airspace Data Interchange Network (NADIN) is being developed, in its initial phase, as a common data communications network that will integrate various FAA communications services, specifically those involved in the exchange of information pertaining to air traffic. Current FAA plans call for the implementation of NADIN in the early 1980s. The initial design is specifically directed to the absorption of the Aeronautical Fixed Telecommunciation Network (AFTN), NASNET, and most of Service B. The design also provides for the expansion of NADIN facilities and circuits so as to accommodate growth, both in terms of requirements for included services and in terms of additional services.

Concurrently with efforts to implement the initial NADIN design, efforts are being directed to the analysis of other services that might be integrated into NADIN. These analyses have two major objectives. First they are to determine if the integration of the specific service into NADIN is cost/beneficial. Second, they are to determine the specific enhancements to NADIN that would be required to absorb that service. This report documents such an analysis conducted with respect to the Flight Data Entry and Printout (FDEP) service.

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SECTION 1

INTRODUCTION

1.1 SUMMARY OF FINDINGS

The FAA Flight Data Entry and Printout (FDEP) service should be integrated into FAA's National Airspace Data Interchange Network (NADIN). This is the major finding from the comparative analysis of alternative strategies for the communications support of FDEP. The specific conclusions from that analysis are:

Conclusion 1: Integration of FDEP into NADIN is more cost effective than independent operation of FDEP.

Use of NADIN concentrators, to interface remote FDEP facilities with FAA's centrally located NAS 9020 computers, would save from $250,000 to $300,000 in comparison with the use of Central Control Units (CCUs) specified for the Flight Data Input/Output (FDIO) program. Should it appear that NADIN will not be implemented until significantly after the FDIO program, the need for timely upgrading of FDEP would dictate the procurement and use of CCUs. Even in that event, the integration of FDEP into NADIN, when available, would save from $50,000 to $100,000 in comparison with the continued operation of the NADIN-independent service.

Conclusion 2: The modification of NADIN to provide local switching for FDEP messages would add approximately $60,000 to the cost, but should facilitate and reduce the cost of subsequent enhancements to NADIN.

The local switching feature would not satisfy any additional needs or provide any additional direct benefits beyond those already available through integration of FDEP into NADIN. Local switching would reduce throughput time on the order of a few seconds and would significantly reduce the amount of NADIN's (currently excess) capacity used for FDEP. The former is not significant, since FDEP performance without local switching will be well within performance requirements. The importance of the latter will depend on the

requirements of other services to be integrated into NADIN. Thus, for example, without the local switching feature, the busiest FDEP system will consume over 20 percent of the initial NADIN concentrator-to-switch trunk capacity.

Conclusion 3: Implementation of an interim NADIN-independent system would add about $200,000 to the cost and thus should be avoided unless the timely upgrading of FDEP is otherwise in jeopardy.

The basic added cost of purchasing CCUs and other associated hardware, firmware, and software is about $468,000. About $261,000 of this cost is expected to be salvageable if FDEP is subsequently integrated into NADIN. The remaining $207,000 is significant, however. Economy would thus suggest that the CCUs and other items in the FDIO program, not required when FDEP is integrated into NADIN, be included only as optional purchase items in the FDIO contract.

The comparative analysis also produced significant results with respect to details for implementing the alternatives. The introduction to Section 3 presents the major findings related to local access circuits; the introduction to Section 4 presents those related to NADIN modifications.

1.2 BACKGROUND

The FDEP service is an important component of FAA's air traffic control system. FDEP is the means by which flight progress data is exchanged between air traffic controllers at remote sites and the NAS 9020 computers located at Air Route Traffic Control Centers (ARTCCs).

FAA is currently pursuing two programs that could significantly upgrade the FDEP service. The first, the FDIO equipment replacement program, will replace old, unreliable equipment (primarily FDEP equipment), with more reliable and technologically advanced equipment. This program will also speed up the FDEP service and reduce FDEP demands on the NAS 9020 computers. The second program, NADIN, will provide a common backbone network for various FAA communications services. This program, also, will reduce demands on the NAS 9020s. FDEP, essentially as upgraded by the FDIO program, is being considered for integration into NADIN following NADIN's initial deployment.

Network Analysis Corporation (NAC), under FAA Contract DOT-FA79WA-4355, was asked to determine the most cost/beneficial approach to support the communications

requirements of the upgraded FDEP service. This report documents that effort and its findings.

1.3 OBJECTIVES

This study addresses one primary and two secondary objectives:

Objective 1: Determine the optimal strategy for the communications support of FDEP.

It was of particular interest to determine if the integration of FDEP into NADIN is more cost effective than the independent operation of FDEP. If integration into NADIN were found to be optimal, it was also of interest to determine if any major enhancements to NADIN (in particular the addition of local switching at NADIN concentrators) were cost effective.

Objective 2: Determine optimal characteristics for FDEP local access circuits.

The architecture of FDEP local access circuits is to undergo major changes as a result of the FDIO program, regardless of the overall strategy selected. In fact, specifications for FDIO provide for local access circuits that should require minimal modification should FDEP be integrated into NADIN. Detailed characteristics of the local access circuits were required to address the primary objective (1) of this study. It was thus convenient to use this effort to develop such details in support of the FDIO program, also.

Objective 3: Determine NADIN modifications required for the integration of FDEP.

This objective, like Objective 2, simultaneously addresses an interim requirement for the primary objective and a separate FAA requirement. The cost of FDEP integration into NADIN includes primarily the costs of associated NADIN modifications. Hence this objective must be addressed in order to address Objective 1. Should NADIN be enhanced to include FDEP, this information would also be required to develop the associated specifications.

1.4 STUDY APPROACH

Three basic strategies for the communications support of FDEP were identified and analyzed. These are:

(1) FDEP operated independently of NADIN, as outlined in the FDIO specifications;

(2) FDEP, as upgraded by FDIO, integrated into NADIN with no major modifications to the basic NADIN concept; and

(3) FDEP integrated into NADIN, with NADIN enhanced to provide local switching.

The analysis was carried out through a series of four subtasks. These were:

- requirements analysis,
- local access design,
- NADIN impact analysis, and
- comparative evaluation.

The following subsections present a brief description of each subtask, together with a discussion of data sources and assumptions.

1.4.1 Requirements Analysis

The first substask established the basis for all successive efforts. Data were collected concerning the nature and environment of the FDEP system. Models were then developed to extend those data into statements of requirements. Section 2 presents the results of those efforts.

1.4.2 Local Access Design

The next subtask developed detailed characteristics for the local access circuits. These were designed so as to be near-optimal for any of the support strategies that were being considered. Section 3 presents the results of that effort and the analysis on which those results were based.

1.4.3 NADIN Impact Analysis

This subtask identified the new functions NADIN would have to perform to support FDEP. It further determined the load FDEP would add to various NADIN components. Section 4 presents the results of those efforts.

1.4.4 Comparative Evaluation

In the final subtask, the differences among the alternatives were converted to dollar measures and compared. Consideration was also given to those differences which could not be measured in terms of dollars. Section 5 presents that evaluation.

1.4.5 Data Sources

Data and other information used as the basis for this study fall into three broad categories:

- current activities,
- projected activities, and
- requirements.

Data related to current activities are generally well documented and are specifically referenced in this report. The major exception is data showing the breakdown of instrument operations at individual FAA sites. Such data were obtained from unpublished FAA computer printouts.

Data related to projected activities were obtained from three major sources — the preliminary FDIO program specifications, the NADIN specifications, and the Terminal Area Forecasts published annually by FAA. In addition, information concerning projected locations of specific equipment (e.g., FDEP replacement equipment and ARTS) were based on unofficial projections by knowledgeable FAA personnel.

Most of the requirements data was obtained from the preliminary FDIO specifications or derived from current and projected activities data. Some data, related to detailed communications system requirements, had to be deduced through informal conversations with FAA personnel.

The published data sources are listed with other references in Appendix F. These are cross-referenced throughout the text by numbers in brackets.

1.4.6 Major Assumptions

This study has been based on a number of key assumptions. Detailed assumptions, pertinent only to the considertions of individual subtasks, are identified in the pertinent section or appendix. The following are the major assumptions used throughout the study:

(1) The FDIO program will be implemented in the next few years, essentially as detailed in the preliminary specification, except perhaps for the procurement of CCUs.

(2) NADIN will be implemented in the next few years, essentially in the form identified as Level I in the NADIN specifications.

(3) Excess NADIN capacity, which will initially be available in the backbone network, can be used for FDEP at no cost.

(4) If CCUs are procured under the FDIO program, and if FDEP is subsequentially integrated into NADIN, components of the CCUs can and will be used as modules for other FDIO control units.

SECTION 2

COMMUNICATIONS ENVIRONMENT AND REQUIREMENTS

2.1 INTRODUCTION

FDEP is that portion of FAA's air traffic control system that provides for the collection of flight progress data by the NAS 9020 computers at the ARTCCs and the dissemination of those data to air traffic controllers at approximately 200 remote sites. The existing FDEP service can no longer perform these functions in a timely manner.

Two FAA programs, FDIO and NADIN, are expected to produce an upgraded FDEP service that will overcome current deficiencies. The FDEP service that evolves must, however, not only meet the current requirement, but must meet the requirements for increasing numbers of remote FDEP sites (nearly 300 by 1982) and for growing FDEP message traffic (expected to increase over 20 percent at a typical site between 1983 and 1991).

This section describes the current FDEP service and the major changes being considered. It also details the requirements that the upgraded service must meet, emphasizing the projected message traffic that must be handled. This information serves as the framework for analyzing and evaluating alternative approaches for the communications support of the upgraded FDEP service.

2.2. THE FDEP SERVICE

The FDEP service is an important component of FAA's air traffic control system. One of the major functions of that system is the collection, processing, and dissemination of flight progress data. FDEP is the subsystem through which such data are collected from and disseminated to flight controllers at approximately 200 remote sites.

Figure 2-1 presents a generalized illustration of FDEP operations. It is assumed for Figure 2-1 that a flight originates at Site #1 with destination at Site #2. ARTCC #1 and ARTCC #2 represent adjacent ARTCCs controlling the areas in which Site #1 and Site #2 are located, respectively. The data transfer process is essentially as follows:

(1) The approved flight plan (originally submitted through FDEP or other means) is transmitted from the NAS 9020 computer at ARTCC #1 to the controllers at Site #1 through a flight strip printer (FSP) at the site.

(2) When the flight departs Site #1, pertinent data is transmitted to the NAS 9020 through an alphanumeric keyboard (ANK) at the site. (If Site #1 has an ARTS facility, this is done automatically by ARTS, rather than through FDEP.)

(3) The flight plan and progress data are transmitted to enroute controllers at ARTCC #1 through an FSP at the ARTCC.

(4) Since the flight will enter an adjacent control area, the NAS 9020 at ARTCC #1 transmits pertinent flight data directly to the NAS 9020 at ARTCC #2.

(5&6) The NAS 9020 at ARTCC #2 transmits the flight plan and progress data to enroute controllers at the ARTCC and airport controllers at Site #2 through their respective FSPs.

(7) When the flight departs Site #2, the process is reinitiated.

This example illustrates the three types of communications requirements associated with the flight progress data:

- remote site to NAS 9020 computer (two-way);
- NAS 9020 to ARTCC controllers (one-way); and
- NAS 9020 to NAS 9020 (two-way).

The FDEP service involves **only** the first of these. The second is referred to as the FSP system and is included in the FDIO replacement program. The third is part of the Computer B service and is included here only for completeness of the illustration.

The FDEP concept of operations is currently undergoing change. To describe FDEP in more detail, it is thus convenient to refer to three operating modes:

- Mode 1, the current service;

- Mode 2, the service as outlined in the specifications for the FDIO equipment replacement program (operating independently of NADIN); and

- Mode 3, the service integrated into NADIN, following implementation of the FDIO replacement program.

2.2.1 Mode 1, The Current Service

The current FDEP service [1] is illustrated in more detail by Figure 2-2. A major component of this system is the Data Communications Control Unit (DCCU). One or more DCCUs are located at each remote site, controlling combinations of up to 2 ANKs and up to 3 FSPs. Messages are interchanged with the NAS 9020 computer over low speed lines (150 baud full-duplex service operating at 74.5 baud half-duplex) using PT&T code. Each DCCU interfaces with the computer through a separate FDEP adaptor port in the computer's peripheral adapator module (PAM).

The FSPs located at the ARTCC are each controlled by a separate Flight Strip Printer Control Unit (FSPCU). Each FSPCU interfaces with the computer through a separate general purpose output (GPO) port in the PAM.

All polling and circuit control is provided by the NAS 9020 computer. In addition, interconnections between the ANKs and their associated message-forming displays (generally the FSPs) are via the NAS 9020. The control units (DCCU and FSPCU) only perform communications functions, e.g., monitoring the status of FSPs and ANKs, responding to polling, handling the communications protocols, inputing and outputing messages received, and basic error checking.

2.2.2 Mode 2, The FDIO Replacement Program

The current FDEP service can no longer perform its intended functions satisfactorily. As a result, too much flight data is not transmitted in a timely manner. This has been due to a combination of many factors. Primary among these are:

- increases in traffic since implementation,

- slow line speeds and print rates,

- poor reliability and maintainability of equipment,

- use of the NAS 9020 for editing, communications control, and other functions that might better be performed by other equipment.

In addition, FDEP requirements for PAM ports (on the order of 20 FDEP ports for remote sites and 50 GPO ports for ARTCC FSPs) limit the use of the NAS 9020 for other functions.

The problems indicated above have made it necessary for FAA to proceed with the FDIO replacement program [2]. This program would provide upgraded service independent of NADIN. Nevertheless, the design of the replacement program is intended to facilitate possible integration of the two programs, should this be desired.

The major elements of the replacement program are:

- replacement of existing ANKs and FSPs with equipment that is faster, more reliable, and generally more technologically advanced; the replacement items are designated, respectively, RANKs and RFSPs;

- replacement of DCCUs with microcomputers;

- use of higher speed lines between remote sites and the ARTCCs; and

- use of microcomputers at the ARTCCs as concentrators for the links to the remote sites and for lines to FSPs at the ARTCC (one microcomputer replacing up to 25 FSPCUs).

The microcomputers will absorb many of the functions now performed by the NAS 9020 and, further, will reduce the number of PAM ports required for the system. The editing function, i.e., the interconnection between a RANK and its message-forming display will be handled by the microcomputer at the remote site, thus reducing the traffic on the link to the ARTCC and the load on the NAS 9020. Polling and circuit control will be carried out by mircrocomputers at the ARTCCs, further reducing the load on the NAS 9020. Figure 2-3 illustrates the expected operation of the system following implementation of the replacement program.

Remote sites involved in the replacement program will have their DCCUs replaced by a microcomputer referred to as a remote control unit (RCU). Each RCU will control up to 10 RFSPs and up to 5 CRT/RANK combinations (CRTs will be used as the message-forming displays where space permits). The International Alphabet No. 5 (IA-5) code will be used. Physical interfaces will comply with EIA standard RS-449. The links to the ARTCC will be via high speed lines (minimum 2400 b/s).

A microcomputer, referred to as a central control unit (CCU), will be installed at each ARTCC. Each CCU will control up to 25 local access circuits. Each CCU will interface with the NAS 9020 computer via a single pair of GPI/GPO ports in the PAM. Remote sites not involved in replacement program (not shown in Figure 2-3) will continue to interface with the computer via dedicated FDEP ports, i.e., such links would not go through the CCU.

Microcomputers, referred to as printer control units (PCU), will replace the FSPCUs at each ARTCC. One PCU will control up to 25 of the RFSPs; i.e., one PCU will replace up to 25 FSPCUs. Each PCU will interface with the computer via one GPO port in the PAM.

It is intended that the RCUs, CCUs and PCUs will be variations of the same basic equipment. Thus, should NADIN eliminate the need for the CCU, that equipment can be used as back-up or replacements for the RCUs and PCUs.

Some of the characteristics of the communications links between RCUs and CCUs were not initially specified. These primarily included:

- network topology, i.e., use of point-to-point or multipoint links;
- line speed (minimum line speed, 2400 b/s, was specified);
- link control protocol (compatibility with NADIN, was specified).

2.2.3 Mode 3, The Replacement Program Using NADIN

NADIN [3] is being developed as a common data communications network to integrate many of the currently separate FAA communications networks and to facilitate the addition of new FAA communications services. Figure 2-4 illustrates the basic elements of the NADIN concept.

NADIN concentrators will be located at each of the 20 ARTCCs within the continental U.S. plus Anchorage, Honolulu, and San Juan. Each concentrator is directly connected to

one of two NADIN switches (backup connection is provided to the second switch, to insure continuity should one switch be down). Each concentrator is also connected to the collocated NAS 9020 and to a variety of terminals located throughout the ARTCC's control area. A message for any service incorporated in NADIN will go from the input terminal (or computer) through the concentrator for the area, to the associated switch. The message is then routed to its destination (output terminal or computer) through the concentrator for the area including that destination or through an external network switch (e.g. WMSC).

Initial implementation of NADIN will primarily include AFTN, Service B (except Computer B) and NASNET. Future enhancements are expected to add other services, including FDEP. Studies related to the enhancements will determine the need to change the basic NADIN architecture, including perhaps the need to add local switching capability to the 23 concentrators.

The approach being considered for the integration of the upgraded FDEP service into NADIN would be to eliminate the CCUs, having the NADIN concentrators perform the CCUs' functions. This approach would appear as shown in Figure 2-5. It is anticipated that, with the appropriate design of the FDIO communication links between the RCUs and CCUs, the integration of FDEP into NADIN would require no significant changes at the remote sites, other than those already included in the FDIO replacement program.

2.3 STRATEGIC REQUIREMENTS

Strategic requirements are those qualitative statements which provide scope and direction to the development of acceptable solutions. Such requirements for the upgraded FDEP service are presented below in terms of three categories — goals, policy constraints, and guidelines.

2.3.1 Goals

The goal of the upgraded FDEP service is to provide FAA air traffic controllers timely information about IFR flights that arrive at, depart from, or overfly the air space under their control and to provide a convenient and timely means for the controllers to transmit flight plans or related data to the NAS 9020 computer at the ARTCC.

2.3.2 Policy Constraints

(1) The design was to involve only state-of-the-art technology and off-the-shelf hardware.

(2) The design was to be consistent with FAA Order 1830.2 [4].

2.3.3 Design Guidelines

(1) The optimal design was to be the one that can meet all other pertinent strategic and tactical requirements at least cost.

(2) The local access circuit design developed through this study was to be compatible with both the FDIO program and the NADIN concept of operations. Primarily this implied a design that:

- includes a communications protocol usable with either mode of implementation;
- is near optimal for either mode; and
- would involve minimal cost and effort in converting from one mode to the other, if needed.

(3) The design was to reflect anticipated growth, both in terms of traffic at existing FDEP sites and in the number of FDEP sites. Emphasis in the analysis was to be placed on the near-range time frame, represented by 1983. However, mid- and long-range time frames, represented respectively by 1987 and 1991 were also to be considered.

(4) The addition of FDEP and other services to NADIN can be expected to affect network performance and possibly to require additional enhancement in order to maintain overall NADIN performance standards. Such enhancements should be addressed in two stages: the first based on the addition of FDEP alone, the

second based on the addition of FDEP and other new services. This study was to address the former; the latter is beyond the scope of this study.

(5) System performance requirements were to be be met during peak operations periods.

2.4 TACTICAL REQUIREMENTS

Tactical requirements are those quantitative statements which govern the development of design details. Such requirements for the upgraded FDEP service are presented below in terms of four categories — system configuration, peak-hour traffic that must be processed, throughput performance, and service availability.

2.4.1 System Configuration

The upgraded FDEP service requires that the RCU at each remote FDEP installation with replacement equipment be connected to the concentrator at its ARTCC and thereby to the NAS 9020 computer at that Center. This connection may be via point-to-point or multipoint lines. The 283 installations that are projected to receive the replacement equipment and their association with ARTCCs are implicitly included in tables presented in Appendix A to this report.

2.4.2 Peak Hour Traffic

Messages are assumed to be generated randomly during the peak hour (i.e., according to the Poisson distribution), resulting in interarrival times that are exponentially distributed. Thus, the probability that the time between any two successive message arrivals is less than t time units is given by:

$$P\{t\} = 1 - \exp\{-Mt\} \; ; \; t \geq 0$$

where M is the average number of messages per time unit.

Appendix A presents estimated values of M for each FDEP site and describes the method by which those estimates were obtained. Data from that appendix are summarized in Table 2-1. Table 2-1 shows for each Center (identified by **LOC**ation **ID**, **CITY**, and **ST**ate):

- the number of remote FDEP sites;
- the expected peak-hour FDEP messages received (IN-TRF) from the remote sites for each of the three time frames; and
- the expected peak-hour FDEP messages transmitted (OUT-TRF) to the remote sites for each of the three time frames.

These data show:

(1) The largest FDEP system is the one associated with the Cleveland Center, having 22 remote sites.

(2) The busiest FDEP system is the one associated with the New York Center.

(3) FDEP traffic is expected to grow over 20 percent between 1983 (near-range) and 1991 (long-range).

(4) There is a large variance in FDEP traffic levels among the 20 systems.

The FDEP messages vary in length from fairly short (i.e. approximately 10 characters) for flight plan amendments to fairly long (i.e. approximately 150 characters) for full, complex flight plans. The majority of the messages will be those transmitted from the Center to the remote sites and will be in the form of full flight plans.

It will be assumed that FDEP message lengths are exponentially distributed with a bias of 10 characters, i.e., no messages will have less than 10 characters. Thus the probability that a message will have length less than c characters is given by:

$$P\{c\} = 1 - \exp\left\{ - (c-B)/(K-B) \right\} ; c \geq B$$

where K is the average number of characters per message and B is the bias (10 characters). K was taken to be equal to 100 characters.

2.4.3 Throughput Performance

The FDIO program specifies the requirement for FDEP throughput performance as "satisfying input and output requirements . . . with delays no greater than 2 minutes during times of peak load." The "delays" referred to are taken to mean (1) for input messages, the time between a message's being ready for transmission at a RCU and the time it is acceptably received at the NAS 9020 computer and (2) for output messages, the time between a message's being ready for transmission at the computer and the time it is acceptably received at the appropriate RCU. In particular, the delays associated with manual entry and RCU-assisted editing of input messages are not included.

This analysis concentrated on the communications links between RCUs and CCUs (or NADIN concentrators). Thus the delay associated with the computer-to-concentrator link was not considered in detail. Rather, the maximum delay specified for the NADIN backbone network, 8 seconds, has been used as a conservative estimate for the delay time associated with that link. This results in the requirement for a maximum delay of 112 seconds between the RCU and the concentrator.

It is generally more convenient to analyze mean delay times rather than "maximums." To convert the requirement to a mean value, it was assumed that the delays were exponentially distributed, i.e.,

$$P\left\{t\right\} = 1 - \exp\left\{-t/D\right\}$$

where $P\left\{t\right\}$ is the probability that the delay is less than t seconds, and D is the mean delay time.

Associating 112 seconds (t) with a very large value of P(t) allows the above expression to be solved for D. Some example results are indicated below:

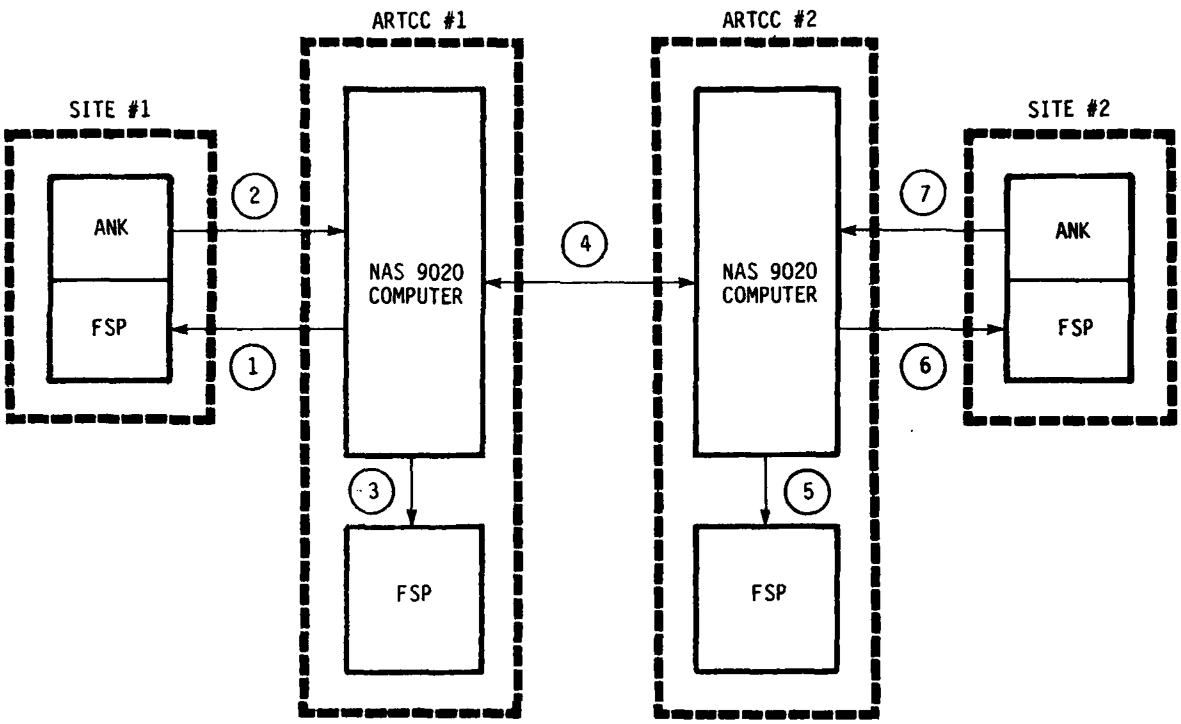
t	P(t)	D
112 sec	.9	48.6
112 sec	.99	24.3
112 sec	.999	16.2

A mean delay of 16.2 seconds, which is seen to be equivalent to having a delay less than 112 seconds 99.9 percent of the time, was used to represent the throughput performance requirement.

2.4.4 Availability

(1) The FDEP service is intended to be in operation 16 hours a day, 7 days a week.

(2) The maximum outage that can be tolerated during operational hours is 15 minutes. This means that, if any element in the FDEP link from local terminals through the communications lines to the computer fails, it must take no longer than 15 minutes to identify the failed element and then to repair, replace, or bypass it.



DATA TRANSFER:

1 FLIGHT PLAN STRIP TO ORIGIN AIRPORT CONTROLLERS

2 FLIGHT DEPARTURE DATA TO COMPUTER

3 FLIGHT PLAN STRIP TO EN ROUTE CONTROLLERS

4 FLIGHT DATA TO COMPUTER FOR NEXT SECTOR TO BE TRAVELED BY FLIGHT

5 SAME AS 3

6 FLIGHT PLAN STRIP TO DESTINATION AIRPORT CONTROLLERS.

7 SAME AS 2

FIGURE 2-1: GENERALIZED FDEP COMMUNICATIONS

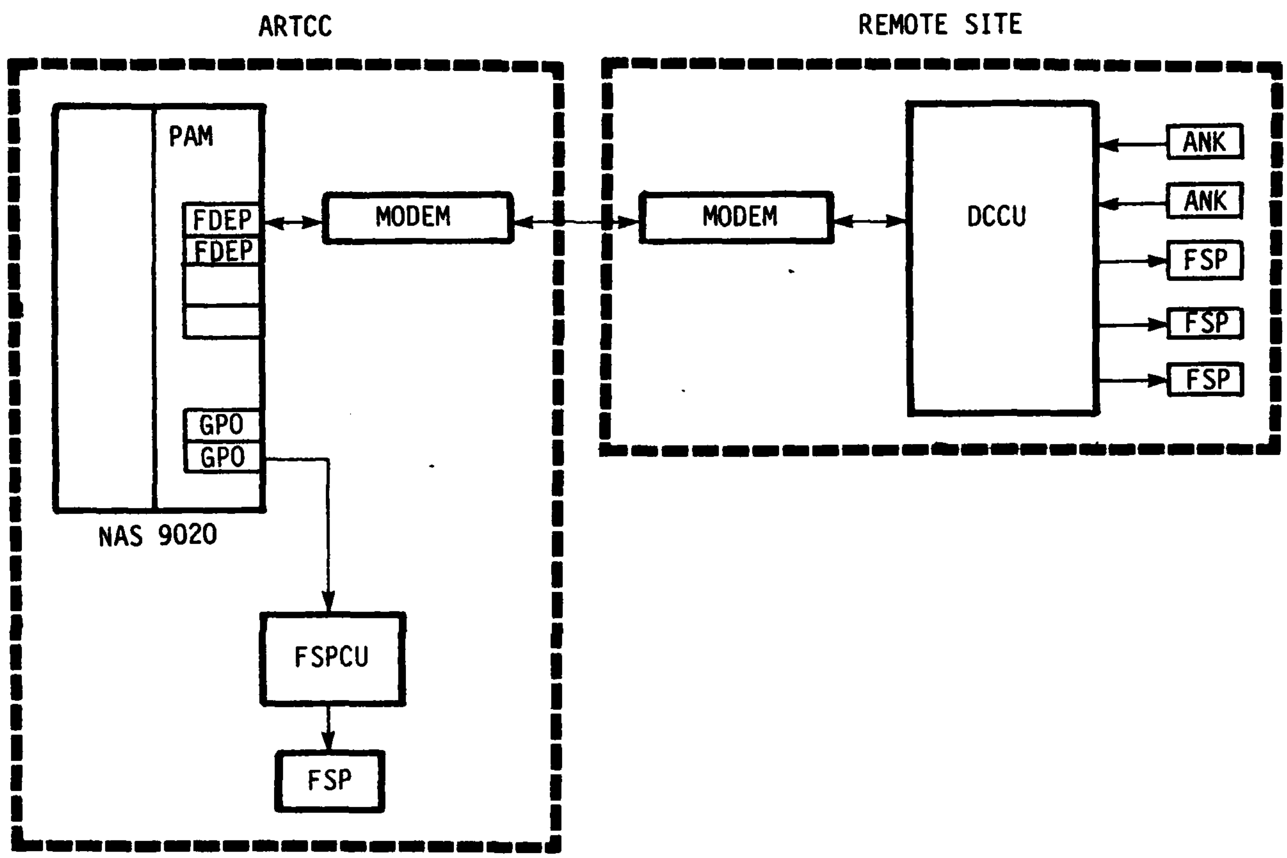


FIGURE 2-2: MODE 1 (CURRENT) COMMUNICATIONS

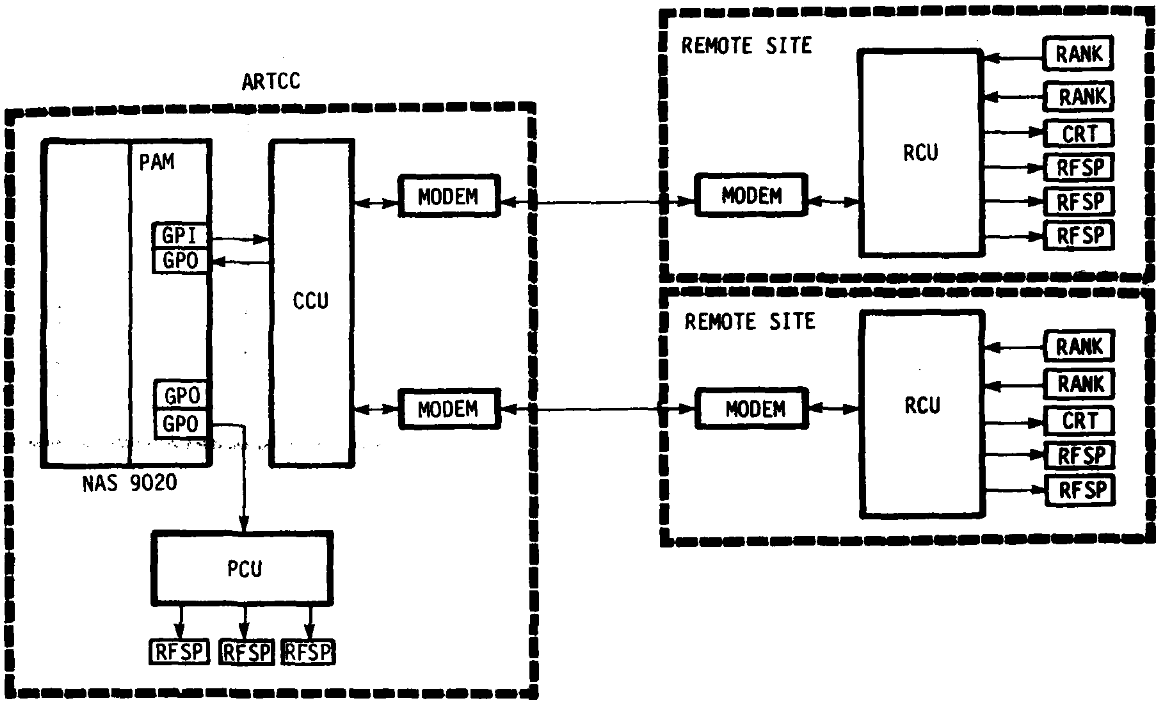
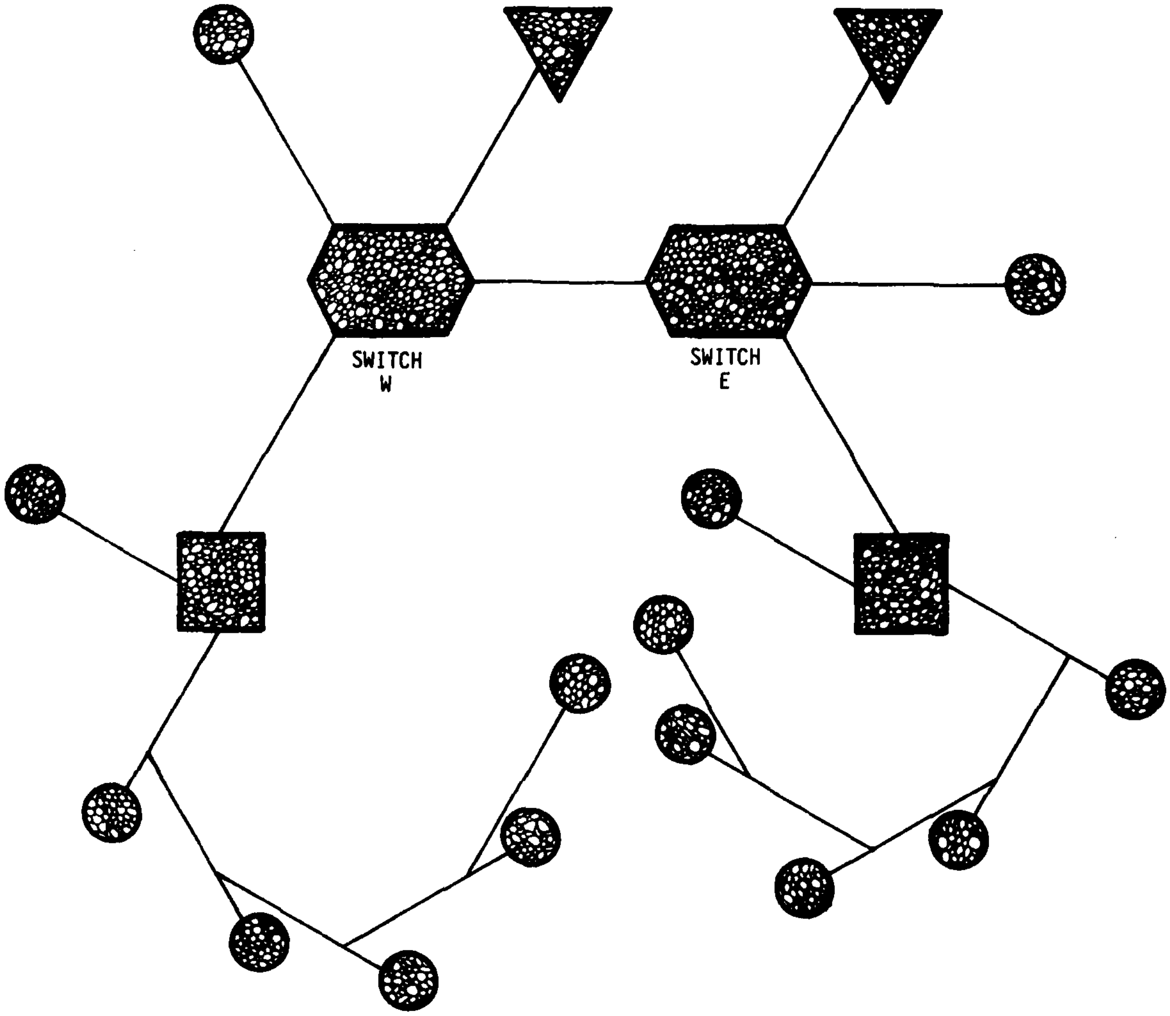


FIGURE 2-3: MODE 2 (REPLACEMENT) COMMUNICATIONS



SWITCHES -- 2 E-ATLANTA, W-SALT LAKE CITY

CONCENTRATORS -- 23 AT EACH ARTCC AND ANCHORAGE, HONOLULU, AND SAN JUAN

TERMINALS -- UP TO ABOUT 50 PER CONCENTRATOR THROUGHOUT EACH ARTCC AREA, PLUS SOME AT SWITCHES. SOME ON DEDICATED CIRCUITS, MOST ON MULTIPOINT

EXTERNAL SYSTEMS AND NETWORKS, E.G., INTERNATIONAL AFTN, WMSC

FIGURE 2-4: NADIN SCHEMATIC

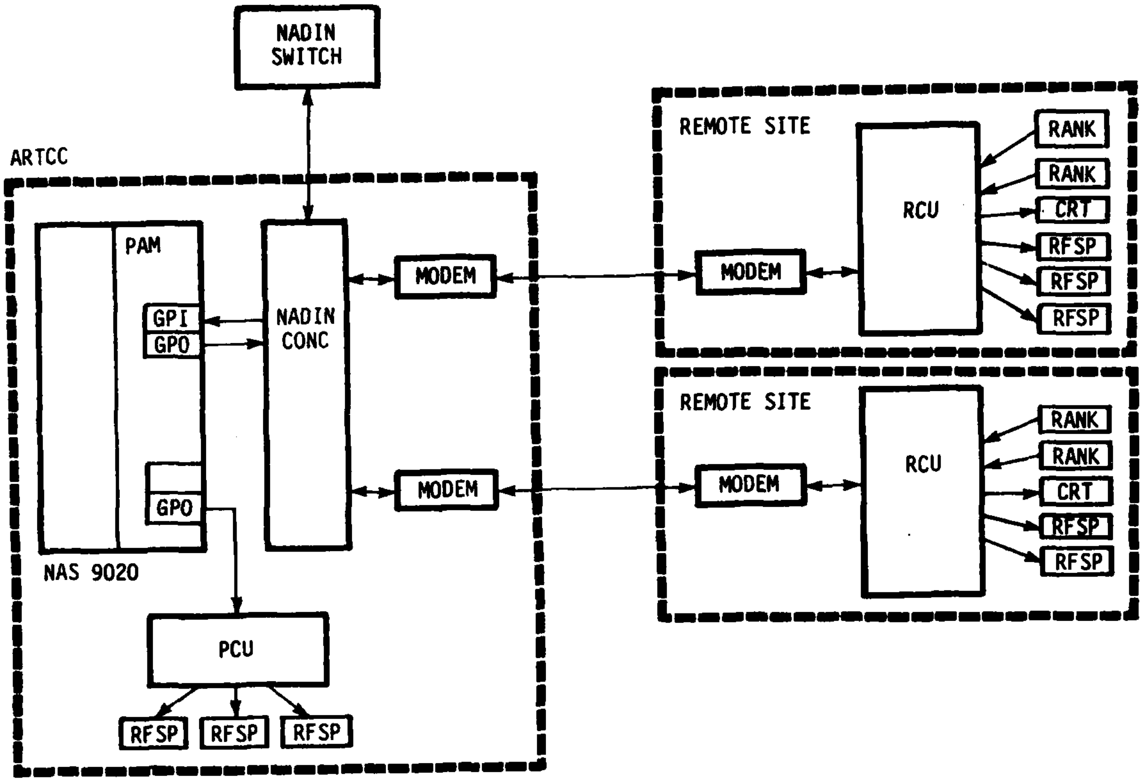


FIGURE 2-5: MODE 3 (NADIN) COMMUNICATIONS

FDEP MESSAGE TRAFFIC AT CENTERS

				NEAR-RANGE		MID-RANGE		LONG-RANGE	
LOCID	CITY	ST	SITES	IN-TRF	OUT-TRF	IN-TRF	OUT-TRF	IN-TRF	OUT-TRF
ZAB	ALBUQUERQUE	NM	8	88	638	94	694	101	737
ZTL	ATLANTA	GA	17	219	1580	247	1773	273	1950
ZBW	BOSTON	MA	15	119	971	132	1093	147	1213
ZAU	CHICAGO	IL	17	256	1539	287	1722	318	1885
ZOB	CLEVELAND	OH	22	280	1775	321	2009	354	2218
ZDV	DENVER	CO	8	55	442	63	497	69	545
ZFW	FORT WORTH	TX	18	303	1444	335	1599	368	1747
ZHU	HOUSTON	TX	17	236	1490	263	1680	293	1850
ZID	INDIANAPOLIS	IN	14	144	1013	166	1159	183	1292
ZJX	JACKSONVILLE	FL	13	95	680	109	766	121	837
ZKC	KANSAS CITY	MO	15	131	800	146	906	162	993
ZLA	LOS ANGELES	CA	18	264	1689	297	1873	321	2045
ZME	MEMPHIS	TN	13	101	709	114	805	128	883
ZMA	MIAMI	FL	11	156	1005	175	1128	193	1242
ZMP	MINNEAPOLIS	MN	14	171	759	190	843	206	921
ZNY	NEW YORK	NY	21	490	2278	543	2543	594	2772
ZOA	OAKLAND	CA	11	311	1533	345	1689	375	1840
ZLC	SALT LAKE CITY	UT	6	104	332	115	366	124	395
ZSE	SEATTLE	WA	13	139	690	158	779	173	856
ZDC	WASHINGTON	DC	12	141	1122	157	1258	174	1382
TOTALS :	20 CENTERS		283	3803	22489	4257	25182	4677	27603

TABLE 2-1:FDEP MESSAGE TRAFFIC AT CENTERS

SECTION 3

LOCAL ACCESS DESIGN

3.1 INTRODUCTION

The design of FDEP local access circuits (i.e., the communications links between RCUs and ARTCC concentrators) served two purposes within this study. First, the design was required as input to the analysis of alternative strategies for the support of FDEP. Second, it was required as input to FAA's efforts to develop specifications for the FDIO program.

Preliminary specifications for FDIO did provide many of the local access design elements, as outlined in Section 2.2.2. This study, thus, primarily addressed the following elements:

(1) use of point-to-point versus multipoint circuits,

(2) concentrator port requirements,

(3) line speed, and

(4) interface control procedures.

3.1.1 Summary of Findings

Analysis of the FDEP communications requirements generated the following conclusions relative to the characteristics for the local access circuits:

Design Conclusion 1: The Advanced Data Communications Control Procedures (ADCCP) should be used as the link level protocol for circuits between the ARTCC and remote FDEP sites.

ADCCP is the only link level protocol currently specified for NADIN that has the flexibility needed for adaptation to communications between the Centers (CCUs or NADIN concentrators) and the RCUs.

Design Conclusion 2: The NADIN control procedure specified for communications between the NAS 9020 computers and NADIN concentrators should be adapted for communications between the NAS 9020s and ARTCC control units obtained as part of the FDIO program (i.e., PCUs and, if pertinent, CCUs).

The control procedures specified for NADIN are easily adapatable to the FDIO equipment. Use of the same basic procedures will facilitate development efforts and the posssible switch-over from CCU to NADIN concentrator use for FDEP.

Design Conclusion 3: Primary communication links between the ARTCCs and remote FDEP sites should use leased lines with 2400 bits per second (b/s) capacity.

The FDIO program calls for equipment compatible with line speeds no lower than 2400 b/s. Performance analysis indicated that there is no need to use any higher line speeds (than 2400 b/s).

Design Conclusion 4: Multipoint circuits, rather than point-to-point connections should be used for primary FDEP service between the ARTCCs and remote sites.

Use of multipoint circuits can save the equivalent of $20,000 per month. In addition, such circuits would significantly reduce the number of concentrator (CCU or NADIN) ports required for FDEP.

Design Conclusion 5: If FDEP is to be integrated into NADIN, the NADIN concentrators must provide up to 10 ports for FDEP.

The optimal line layouts for the individual FDEP systems require from 2 to 5 ports for primary service circuits and 4 or 5 ports for dialed back-up service. The smallest total port requirement is 6 (for Denver); the largest is 10 (for New York and Los Angeles).

3.1.2 General Approach

The four local access design elements addressed in this study are all interrelated and can, thus, not generally be treated separately. Nevertheless, it proved feasible for this study to use the following sequential approach:

- First a subjective analysis of interface control requirements was conducted, leading to procedures that are applicalbe to point-to-point circuits, multipoint circuits or a combination of the two.

- Next a generalized performance analysis was conducted. This was intended to isolate constraints on line speed or circuit size (i.e., RCUs per circut), or combinations of the two, needed to insure that the system met performance requirements.

- Next a line layout analysis was conducted, producing least cost layouts using various combinations of constraints. Overall optimal layouts were selected from those results.

- Finally, an analysis was conducted to determine the number of back-up (point-to-point) circuits that would be required to maintain performance requirements despite expected primary communications outages.

3.2 INTERFACE CONTROLS

Three types of FDEP communications links require interface controls. These are:

- the NAS 9020-to-concentrator (CCU or NADIN) links,

- the concentrator-to-RCU links, and

- RCU-to-terminal links.

Interface controls for the latter are transparent to NADIN and will be developed by the FDIO contractor. This study addressed only the first two.

3.2.1 NAS 9020-To-Concentrator Links

The NADIN specifications completely define the interface controls required for the NAS 9020-to-concentrator links. These were found to be easily adaptable to NAS 9020-to-

CCU links. Further, the same basic controls are easily adaptable to the NAS 9020-to-PCU links. Appendix B details the recommended adaptations.

3.2.2 Concentrator-To-RCU Links

This interface may involve either NADIN concentrators or CCUs. The NADIN specifications already require a series of interface controls for the NADIN concentrator, some of which could be adapted for the interface with RCUs. In developing the interface control requirements for these links, the following criteria were thus used:

- the NADIN interface controls selected for adaptation should require minimal change;

- the procedures at the RCU ends should be essentially the same, whether the CCUs or NADIN concentrators are used — i.e., possible conversion from CCU use to NADIN should involve minimal, if any, changes in the RCU firmware.

The interface control requirements defined for these links are also detailed in Appendix B. The major features include:

(1) use of NADIN message format,

(2) use of the Advanced Data Communications Control Procedures (ADCCP) [5] as the link protocol, and

(3) use of dial-up, switched, voice-grade lines for back-up service when primary leased connections are down.

3.3 PERFORMANCE ANALYSIS

The performance analysis determined the constraints that would subsequently be applied in the line layout analysis, so as to insure achievement of the specified throughput requirement. That requirement (see Section 2.4.3) limits the communications delays between RCUs and the ARTCC concentrators so that the mean is no greater than 16.2 seconds (or so that delay is no greater than 112 seconds, 99.9 percent of the time).

3.3.1 Performance Model

The design variables with significant impact on the throughput delay primarily include:

- the link protocol used,
- the line speed,
- the size of individual circuits (i.e., RCUs on a single circuit), and
- the message traffic level (message frequency and length).

The delay should decrease with increasing line speed and increase with increasing circuit size and traffic level. The impact of the link protocol is more complex.

The first step in the performance analysis was thus the development of a mathematical model reflecting the specified link protocol, ADCCP. That model (detailed in Appendix C) estimates the mean throughput delay for an individual circuit as a function of:

- the number of RCUs on the circuit,
- the peak-hour message traffic volume, and
- the mean message transmission times (reflecting message length and line speed).

3.3.2 Model Application

Initial application of the model focused on "worst case" situations. The busiest FDEP system, i.e., the one associated with the New York ARTCC, was thus used for this analysis. The major model inputs were determined as follows:

- A single multipoint circuit was assumed, with all 21 RCUs on that circuit.
- Multiples of the 1991 message traffic volumes (see Appendix A) were used.

- Average transmission times were calculated as shown in Table 3.1, assuming a mean message length of 100 characters, a line speed of 2400 b/s, and a 60 percent overhead per message (this latter is discussed in Section 4.3.3.).

Figure 3-1 shows the resulting mean throughput delays as a function of messge traffic volume. Four delay curves are shown in that figure. Part A shows the throughput delays for the average output (NAS 9020-to-RCU) and average input (RCU-to-NAS 9020) messages. Part B shows the throughput delays for input messages from two selected remote sites — La Guardia, LGA, the site with the most input messages and Trenton, TTN, the site receiving the fewest output messages (and hence the fewest polls when the system approaches saturation).

3.3.3 Implications of Performance Analysis

The curves in Figure 3-1 are fairly typical in that they show very little change in throughput delay as the traffic level increases over most of the applicable range of values. As the system approaches saturation, however, delay time increases rapidly with small changes in traffic level. Saturation occurs when the rate at which messages are generated approaches the rate at which they can be transmitted. For the illustrated worst case condition, this is seen to occur at about 1.8 times the projected 1991 traffic level.

It can also be noted that, even at traffic levels as high as 1.5 times the 1991 projections, the mean delays are well below the specified constraint (16.2 seconds). Since these results apply to the worst case, i.e, all 21 RCUs in the busiest FDEP system on one 2400 b/s multipoint circuit, throughput performance for more typical cases (less than 10 RCUs on a circuit) will be even better.

From these results it can be concluded that:

- there is no need to use line speeds greater than 2400 b/s; and

- circuit size (i.e, RCUs on a single circuit) need not be constrained to insure the desired throughput performance.

3.4 LINE LAYOUT ANALYSIS

The line layout analysis determined optimal (least cost) local access circuits for each FDEP system. Three categories of costs were considered in this optimization:

- monthly primary service costs,
- monthly back-up service costs, and
- one-time costs.

3.4.1 Primary Service Analysis

The primary service analysis made use of NAC's proprietary network design program, GRINDER. That program identifies minimal cost line layouts reflecting input cost parameters and specified constraints.

The only costs considered for this analysis were those recurring costs that would differ among the various layouts for FDEP; i.e., those associated with the government TELPAK tariff. These were presented as:

- \$.5417 per mile of line per month, and
- \$43.30 per drop per month, including one at each RCU and one at the ARTCC for each circuit.

Generally, the lesser cost layouts would involve fewer circuits with more remote drops (RCUs) per circuit. This generalization is limited by the geography of the system; e.g., rarely will it be economical to include two sites on opposite sides of the ARTCC in the same circuit. Further, as more drops are added to individual circuits, throughput delays increase and availability of connections is reduced. The former results from increased polling delays as more RCUs need to be polled; the latter, from the increased number of connections to the ARTCC that could be broken by the outage of a single link. The performance analysis (Section 3.3.3) indicated that the throughput requirements would be met with 2400 b/s lines (which are assumed here), even if there were no constraint on circuit size. Thus, the only constraints of interest were those associated with communications availability.

The impact of availability on optimal line layouts is illustrated in Figure 3-2. For this illustration, line layouts and associated primary service costs were generated for the New York Center FDEP system. GRINDER was used with the circuit size constrained, in turn, to a maximum of 1, 3, 5, 7, and 10 RCUs on a single circuit. Availability of the primary service is reflected by the cost of the associated back-up service requirement. Such costs were determined for each GRINDER-generated layout (as discussed in Section 3.4.2, below).

Figure 3-2 is fairly typical. For the system illusrated, the layout with the least primary service cost is seen to involve 10 or more remote drops on a circuit. The layout with the least back-up service cost will always be the one involving only point-to-point circuits (maximum circuit size = 1). The layout with the least total (primary plus back-up) cost will generally lie between the two extremes. Here, the minimum is seen to result when the circuit constraint is 5 RCUs.

Spot checks for other FDEP systems suggested that the optimal line layouts, relative to total recurring costs, could be obtained from GRINDER by setting the circuit size constraints to values in the range of 3 to 7 RCUs. This range was thus used to generate a series of near-optimal line layouts for each of the 20 FDEP systems. The resulting line layouts and the associated recurring costs are included in Appendix D. Figure 3-3 shows graphic examples of the line layouts generated by GRINDER. Specifically, that figure shows layouts produced when the circuit size constraint was set to 5.

3.4.2 Back-Up Service Costs

For this analysis, back-up FDEP service is assumed to be provided through standard half-duplex, voice-grade, dialed circuits. This service costs approximately twenty cents per minute ($12.00 per hour) of actual usage. Thus in a typical month of 30 days, with the FDEP systems operating 16 hours per day (i.e., 480 hours per month), the cost for a single remote site will be:

$$C_A = \$12.00 \times 480 \times (1.0 - A)$$

where C_A is the average monthly back-up service cost for the site, and

A is the fraction of the time that the primary service connection to the ARTCC is available.

In order for a connection to be available, the following conditions must all exist:

- the modem at the remote site must be operational,
- the modem at the ARTCC must be operational, and
- every circuit link (i.e., the lines between successive drops) between the remote site and the ARTCC must be up.

The availability of a connection can thus be determined from:

$$A = A_M^2 \times A_L^N$$

where A_M is the fraction of time that a specific modem is functioning properly during operational hours (typical value = .999),

A_L is the fraction of the time that an average link on a multipoint line is up (typical value = .997), and

N is the number of circuit links between the remote site and the ARTCC.

Table 3-2 shows values for the availability (A) and the associated costs (C_A) as a function of the number of links (N). These values were calculated by using the typical values for A_M and A_L, shown above.

The back-up service costs for the line layouts shown in Appendix D were determined as follows:

- For each remote site, the number of links, N, between the site and the ARTCC were noted.
- The associated cost, C_A, was then obtained from Table 3-2.
- These costs were totaled over all sites associated with each system, to determine the back-up service cost for the system (these costs are also shown in Appendix D).

- Finally, the back-up service costs were added to the primary service costs to obtain total monthly costs.

Table 3-3 shows the total monthly costs obtained for each FDEP system, under four circuit size constraints. Included in these is the comparable cost for point-to-point circuits (circuit size constraint = 1).

3.4.3 One-Time Costs

The analyses discussed above considered only the recurring costs that differ among the various line layouts. There are also two possible one-time costs that would vary:

- the cost of modems at the ARTCC (at least one per circuit and one per back-up service port), and

- the cost of NADIN concentrator ports (CCUs would be procured with exactly 25 ports, regardless of layout used).

An equivalent monthly cost associated with a one-time cost can be determined from:

$$M = C \times d \times \left[1-(1+d)^{-m} \right]^{-1}$$

where M is the equivalent monthly cost,

C is the one-time cost,

d is the discount rate (per month), and

m is the expected life of the equipment (in months).

Modems for 2400 b/s full-duplex lines range in cost from \$2000 to \$3000 apiece. NADIN concentrator ports have been estimated to cost approximately \$200 apeice. This equipment is considered to have a life of 7 years or 84 months. Thus, for the calculations of equivalent monthly cost, C was set to \$2700, n to 84 and d was taken as .00833 (reflecting

an annual discount rate of 10 percent). This yields an equivalent monthly cost of approximately $45 per port.

The number of concentrator ports required for each line layout is indicated in Table 3-4. These values were determined as follows:

- Primary service port requirements for the multipoint line layouts were obtained from Apendix D; i.e., one port is required for each circuit in each system.

- Primary service ports required for point-to-point layouts (i.e., circuit size constraint = 1) are equal to the number of remote drops (RCUs) in the system.

- All but four of the systems required five back-up service ports for the three multipoint line layouts. The four exceptions —Albuquerque, Denver, Miami, and Salt Lake City — required only four. Section 3.5, below, discusses this determination.

- All systems with less than 15 remote drops require only one back-up service port for point-to-point layouts. All with 15 or more remote drops require two. This is also discussed in Section 3.5.

The data included in Table 3-4 includes the total requirement only for "base" layouts; i.e., those asociated with the 7 RCU per circuit constraint. The remaining columns show the differences between the total requirement for the specific layout and that for the associated base layout requirement.

Table 3-5 shows the overall equivalent monthly cost for the various layouts. Those values were obtained by adding $45 to the monthly costs (shown in Table 3-3) for each added port (shown in Table 3-4). No one-time port costs were added to the base layouts.

3.4.4 Implications of Line Layout Analysis

The above analysis identified the optimal line layout for each of the 20 FDEP systems. Table 3-6 presents summary data for these layouts and references the associated detailed layouts in Appendix D.

Use of the optimal layouts will result in the following:

(1) a savings of over $20,000 per month in comparison with point-to-point circuits,

(2) a requirement for 6 to 10 concentrator ports for each system (including back-up service ports), and

(3) average throughput delays less than 16.2 seconds.

3.5 PORTS FOR BACK-UP SERVICE

The back-up service is intended to increase the availability of communications between the remote sites and the Center. Analysis of the proposed primary communications links indicated that the FDEP systems with fewer remote sites will have some primary service outage about three percent of time and the systems with more remote sites, about ten percent of the time. Such outages occur if either a modem or circuit link connecting a remote site to the concentrator is down. An outage of the combined primary/back-up service occurs only when the primary service is out for more remote sites than there are back-up FDEP service ports at the concentrator. (The very small likelihood that a back-up line or modem is out when required is ignored.)

The availability of the combined service thus depends on the number of simultaneous primary service outages and the number of back-up ports available. If, for example, there are five back-up ports and five or less primary service outages are expected 99 percent of the time, combined outages can be expected to occur 1 percent of the time.

The analysis to determine back-up port requirements has been carried out in three steps:

- analysis of primary service availability, with emphasis on the number of simultaneous outages for each Center;

- conversion of those results into measures of individual connection availability, when considering the combined primary/back-up service; and

- determination of the minimum number of back-up ports that will insure that the combined service satisfies system requirements.

3.5.1 Primary Service Availability

The individual FDEP systems were modeled, using Monte Carlo simulation techniques, to determine the likelihood that specific numbers of remote sites did not have a primary connection to the Center at the same time. Each modem was represented as having an availability (probability of being up) of .999 and each link of the circuit (i.e., that portion of the line between successive drops) was represented as having an availability of .997. A given remote site was considered as having lost its primary connection if:

- the modem at the associated Center was down,
- the remote site's modem was down, or
- any circuit link between the remote site and the Center was down.

The output from each replication was the number of sites without primary connection.

For this analysis, the multipoint line layouts developed in Appendix D were used for each FDEP system. The simulation was replicated 2000 times for each system.

Table 3-7 shows the frequency distribution of the results using the layouts generated with the 5 RCU per circuit constraint. Those results indicate, for example:

- the New York Center system had no broken primary connections 90.5 percent of the time, more than 4 broken connections about 1 percent of the time, and more than 6 broken connections 0.1 percent of the time;
- the Indianapolis Center system has no broken primary connections 93.5 percent of the time, more than 4 broken connections about 1 percent of the time, and never had more than 6 broken connections (in the 2000 simulated instances).

Thus, if each concentrator provided four ports for back-up service, both the New York and Indianapolis Center systems would still be expected to experience outages of the combined primary/back-up service about 1 percent of the time.

3.5.2 Individual Connection Availability

In order to obtain a better perspective of the results obtained from the simulations, those results were converted into measures of individual system availability per day under the combined primary/back-up service. Under the combined service, outages are considered to exist only when there are more primary service outages than there are back-up service ports. Thus, if there are P back-up ports, the mean number of combined service outages at any time will be:

$$MCO(P) = \sum_{J=P+1}^{NS} (J-P) \times f(J)$$

where MCO(P) is the mean number of combined service outages at any instant;

NS is the number of remote sites in the system;

f(J) is the frequency distribution function for the number of simultaneous primary service outages: i.e., the fraction of the time that exactly J *remote sites do not have primary connections* (essentially the data in Table 3-7).

MCO(P) can also be interpreted as the mean number of site-hours of combined service outage per hour of operation for the entire system. Thus the expected outage for one site over one (16-hour) day would be:

$$MTO(P) = MCO(P) \times 3600 \times 16/NS$$

where MTO(P) is the mean number of seconds of combined service outage expected per site per day.

Extreme cases can be estimated by using an exponential distribution to approximate the distribution of outage time per site per day. Thus:

$$Q(s,P) = e^{-s/MTO(P)}$$

where $Q(s,P)$ is the probability that there are s or more seconds of combined service outage at one site in one day.

Solving the above expression for s provides a means of determining the various percentiles of the distribution. Thus:

$$\bar{s}(q,P) = (-\ln q) \times MTO(P)$$

where $\bar{s}(q,P)$ is the value of s that would make $Q(s,P) = q$; i.e., values greater than or equal to $\bar{s}(q,P)$ are expected to occur with frequency q.

In particular, the 99.9 percentile can be determined by setting $q = 0.001$. Then:

$$\bar{s}(0.001, P) = 6.91 \times MTO(P).$$

Table 3-8 shows values of MCO(P), and MTO(P), and $\bar{s}(0.001,P)$ for the New York Center system (worst case) and the Indianapolis Center system (representative case) based on line layouts associated with the 5 RCU per circuit constraint. Data in that table reflects the number of back-up ports ranging from 0 to 7, and the number of remote sites equal to 21 for New York and 14 for Indianapolis.

3.5.3 Back-up Port Requirements

In Section 2.4.4 the availability requirement was identified as a maximum outage of 15 minutes (900 seconds). Table 3-8 indicates that this can be achieved 99.9 percent of the time for both the New York and Indianapolis example systems, if three or more back-up ports are provided.

Communications outages also have the effect of increasing throughput delays for messages ready for transmission during the outages. In Section 2.4.3 the performance requirement was identified as a throughput delay between remote sites and concentrator of less than 112 seconds (at least 99.9 percent of the time) or a mean delay of 16.2 seconds. The performance analyisis (Section 3.3) produced a very conservative upper bound of 5 seconds for the mean throughput delay (not considering possible outages). If the extreme outages shown in Table 3-7 were continuous, at least 5 back-up ports would be required for

the New York and Indianapolis Center concentrators in order to keep all but the most extreme cases within the 112 second delay requirement.

Without data on the distribution of outage duration, no better estimate of the backup port requirement is possible. Because of the conservative nature of the analysis, however, it should be clear that no more than 5 ports are required.

Similar analyses for all 20 systems and line layouts based on circuit size constraints of 7, 5, 3, and 1 RCU per circuit yielded the following:

- For the three multipoint line layouts, five back-up service ports should be provided for all but four systems. The four exceptions — Albuquerque, Denver, Miami, and Salt Lake City — should be provided with only four such ports.

- With the point-to-point layouts (circuit size constraint = 1), only one back-up service port is required for those systems with less than 15 remote drops. For those systems with 15 or more remote drops, 2 such ports are required.

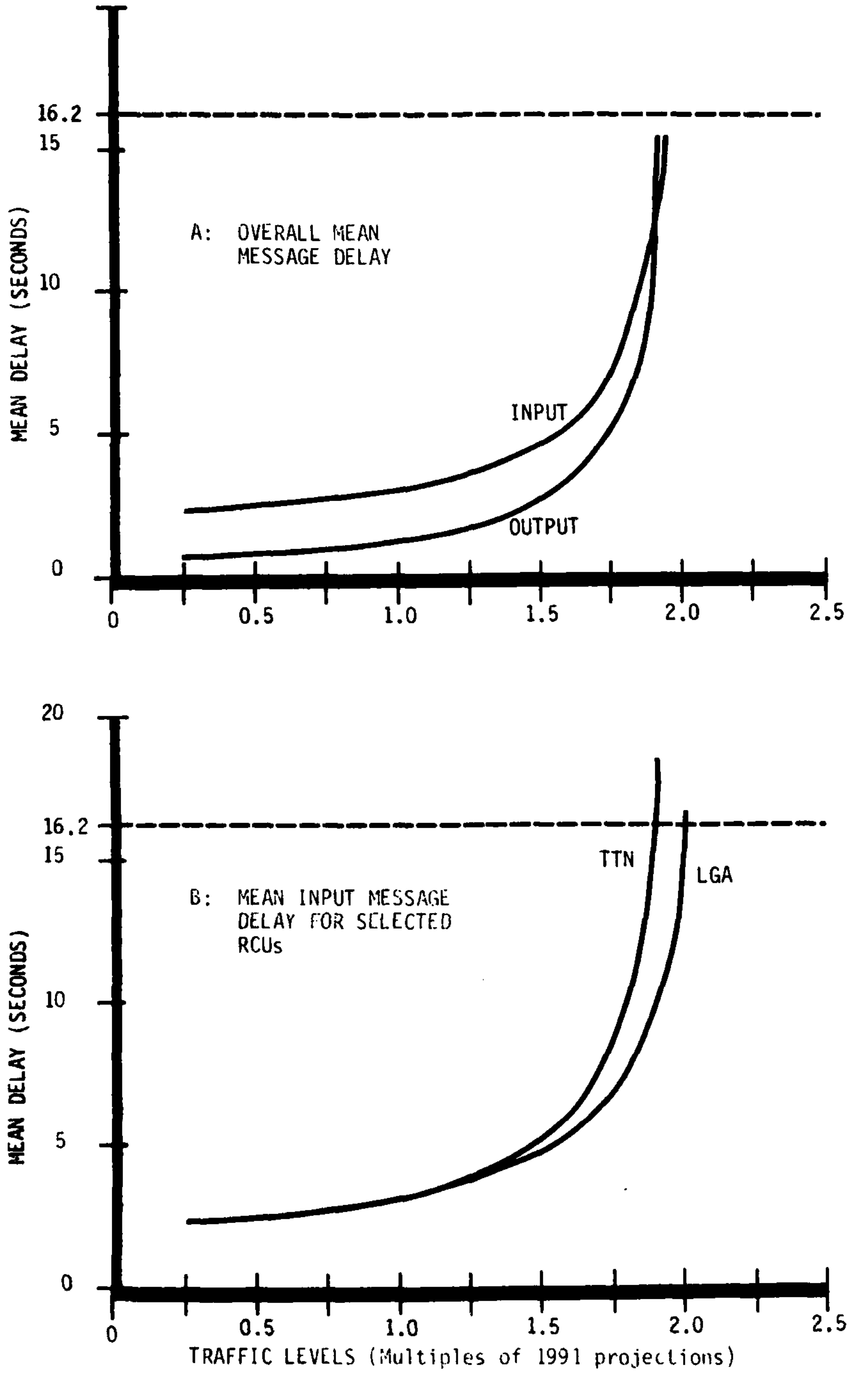


FIGURE 3-1: MEAN MESSAGE DELAYS, WORST CASE CONDITIONS

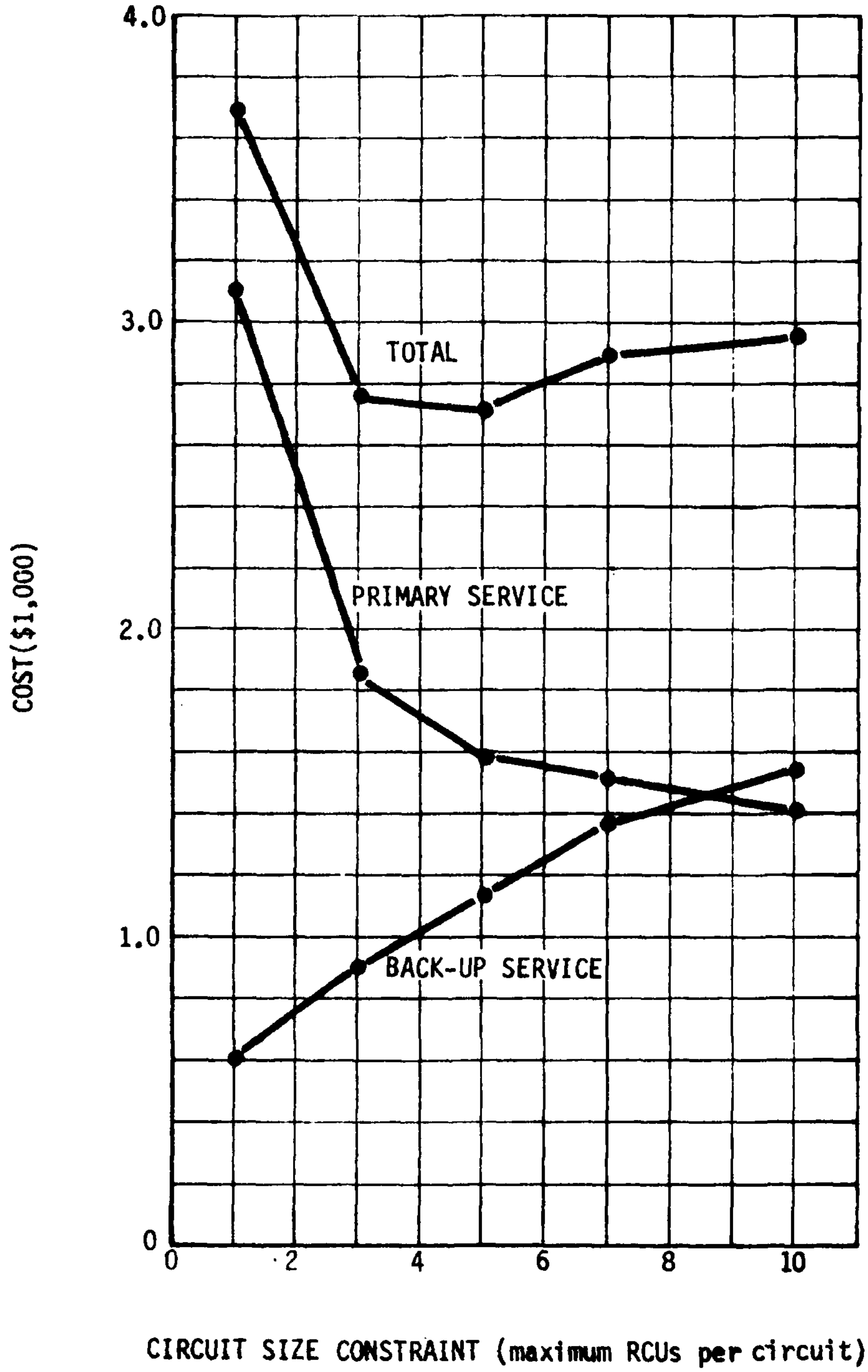
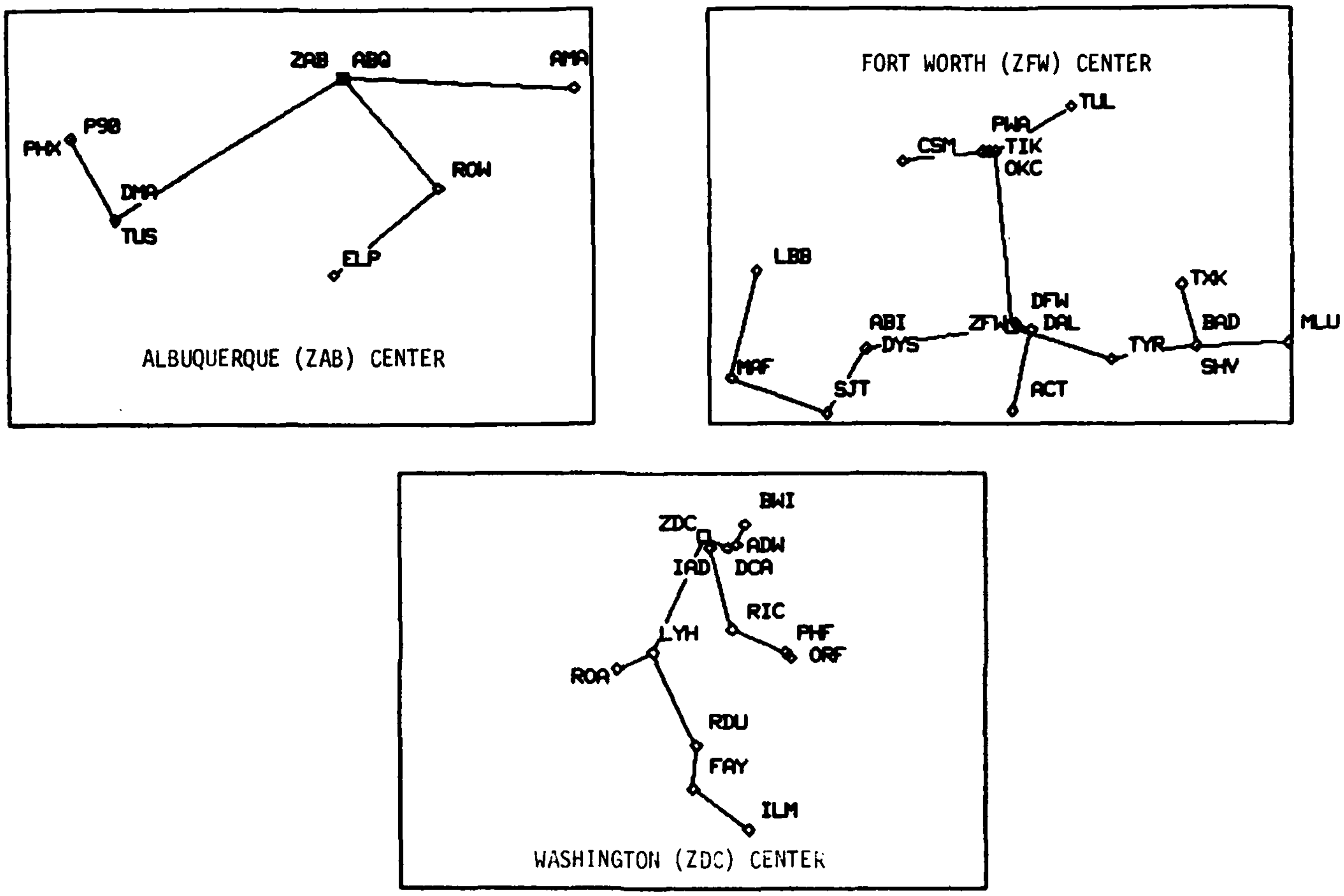


FIGURE 3-2: COMMUNICATIONS COSTS VS. CIRCUIT SIZE



<u>FIGURE 3-3: EXAMPLE LINE LAYOUTS PRODUCED BY GLAD</u>

COMPONENT	CHARACTERS	BITS (8 per char)	DELAY (sec.) MSG. FRAME	CONTROL FRAME
Source Processing			.0500	.0002
Message Transmission	100	800	.3334*	----
Overhead Transmission	60	480	.2000*	----
Control Frame Trans.	6	48	----	.0200*
Propagation Delay			.0150	.0150
Destination Processing			.0500	.0002
		TOTAL	.6484	.0354

*Line Speed = 2400 bits per second

TABLE 3-1: TRANSMISSION DELAYS

LINKS (N)	AVAILABILITY (A)	BACK-UP COST (C_A)
1	.9950	$ 28.80
2	.9920	45.96
3	.9890	63.12
4	.9861	80.16
5	.9831	97.20
6	.9802	114.24
7	.9772	131.16
8	.9743	148.08
9	.9714	164.88
10	.9685	181.68

TABLE 3-2: MONTHLY AVAILABILITY COSTS

CENTER	CIRCUIT SIZE CONSTRAINT (Max RCUs per Circuit)			
	7	5	3	1
Albuquerque (ZAB)	$1399*	$1399*	$1494	$1989
Atlanta (ZTL)	2438	2468	2413*	3284
Boston (ZBW)	2138	2059	2041*	2707
Chicago (ZAU)	2409	2327*	2391	3035
Cleveland (ZOB)	2964	2955	2934*	3942
Denver (ZDV)	1233	1227*	1241	1492
Fort Worth (ZFW)	2804	2678*	2813	3813
Houston (ZHU)	2708	2540*	2602	3860
Indianapolis (ZID)	1996	1956*	2001	2597
Jacksonville (ZJX)	2047*	2047*	2051	2726
Kansas City (ZKC)	2393	2273*	2285	3177
Los Angeles (ZLA)	2490	2289	2242*	2654
Memphis (ZME)	2124	2090	2062*	2664
Miami (ZMA)	1442*	1442*	1505	2030
Minneapolis (ZMP)	2330*	2365	2375	3315
New York (ZNY)	2888	2717*	2760	3702
Oakland (ZOA)	1551	1438	1424*	1665
Salt Lake City (ZLC)	1206*	1206*	1319	1772
Seattle (ZSE)	1836	1798*	1820	2504
Washington (ZDC)	1698	1646*	1702	2444

*Indicates minimum for each Center

TABLE 3-3: MONTHLY COMMUNICATIONS COSTS

CENTER	BASE REQUIREMENT CSC = 7	ADDED PORT REQUIREMENTS CSC = :		
		5	3	1
Albuquerque	7	0	1	2
Atlanta	8	1	3	11
Boston	9	0	2	8
Chicago	8	1	3	11
Cleveland	9	1	4	15
Denver	6	1	1	3
Fort Worth	9	0	3	11
Houston	8	1	3	11
Indianapolis	7	1	3	8
Jacksonville	8	0	2	6
Kansas City	8	1	2	9
Los Angeles	10	0	2	10
Memphis	8	0	2	6
Miami	7	0	2	5
Minneapolis	8	1	3	7
New York	9	1	4	14
Oakland	9	0	1	3
Salt Lake City	7	0	1	0
Seattle	7	1	3	7
Washington	7	1	3	6

NOTE: CSC = Circuit Size Constraint

TABLE 3-4: CONCENTRATOR PORT REQUIREMENTS

CENTER	TOTAL EQUIVALENT MONTHLY COST, CSC = :			
	7	5	3	1
Albuquerque	$1399*	$1399*	$1539	$ 2079
Atlanta	2438*	2513	2548	3779
Boston	2138	2059*	2131	3067
Chicago	2409	2372*	2526	3530
Cleveland	2964*	3000	3114	4617
Denver	1233*	1272	1286	1627
Fort Worth	2804	2678*	2948	4308
Houston	2708	2585*	2737	4355
Indianapolis	1996*	2001	2136	2957
Jacksonville	2047*	2047*	2141	2996
Kansas City	2393	2318*	2375	3582
Los Angeles	2490	2289*	2332	3104
Memphis	2124	2090*	2152	2889
Miami	1442*	1442*	1840	2345
Minneapolis	2330*	2410	2510	3630
New York	2888	2762*	2940	4332
Oakland	1551	1438*	1465	1800
Salt Lake City	1206*	1206*	1364	1772
Seattle	1836*	1843	1955	2819
Washington	1698	1691*	1837	2714
TOTAL		$41,173**		$62,302

NOTES:

CSC = CIRCUIT SIZE CONSTRAINT

*INDICATES MINIMUM FOR EACH CENTER

**SUM OF MINIMUMS

TABLE 3-5: TOTAL MONTHLY EQUIVALENT COSTS

CENTER	EQUIVALENT MONTHLY COST	CONCENTRATOR PORTS	CSC USED*	REMOTE SITES
Albuquerque	$ 1,399	7	5 or 7	8
Atlanta	2,438	8	7	17
Boston	2,059	9	5	15
Chicago	2,372	9	5	17
Cleveland	2,964	9	7	22
Denver	1,233	6	7	8
Fort Worth	2,678	9	5	18
Houston	2,585	9	5	17
Indianapolis	1,996	7	7	14
Jacksonville	2,047	8	5 or 7	13
Kansas City	2,318	9	5	15
Los Angeles	2,289	10	5	18
Memphis	2,090	8	5	13
Miami	1,442	7	5 or 7	11
Minneapolis	2,330	8	7	14
New York	2,762	10	5	21
Oakland	1,438	9	5	11
Salt Lake City	1,206	7	5 or 7	6
Seattle	1,836	7	7	13
Washington	1,691	8	5	12
TOTAL	$41,173	164		283

*CSC = Circuit Size Constraint — identifies specific line layouts from Appendix D to which the data apply.

TABLE 3-6: OPTIMAL LINE LAYOUTS

CENTER J =	FRACTION OF TIME J SIMULTANEOUS PRIMARY OUTAGES EXPECTED, F(J) 0	1	2	3	4	5	6	7 or more
Albuquerque	.967	.018	.008	.004	.003	----	----	----
Atlanta	.921	.031	.010	.014	.016	.007	.001	----
Boston	.929	.035	.011	.005	.010	.009	.001	----
Chicago	.922	.037	.014	.009	.002	.015	.001	----
Cleveland	.904	.044	.011	.011	.018	.011	----	.001
Denver	.961	.016	.010	.006	.007	----	----	----
Fort Worth	.916	.037	.010	.014	.010	.012	----	.001
Houston	.923	.030	.012	.015	.009	.010	----	.001
Indianapolis	.935	.032	.015	.004	.004	.009	.001	----
Jacksonville	.938	.021	.012	.011	.009	.009	----	----
Kansas City	.929	.032	.012	.016	.007	.003	.001	----
Los Angeles	.915	.041	.013	.016	.011	.004	----	----
Memphis	.941	.022	.013	.011	.008	.004	----	.001
Miami	.948	.024	.010	.008	.010	----	----	----
Minneapolis	.935	.041	.008	.004	.004	.007	.001	----
New York	.905	.045	.009	.013	.017	.008	.002	.001
Oakland	.947	.029	.009	.004	.004	.007	----	----
Salt Lake City	.972	.021	----	.004	.003	----	----	----
Seattle	.939	.026	.019	.008	.001	.006	----	.001
Washington	.942	.029	.009	.012	.003	.005	----	----

NOTE:

---- indicates that associated value of J did not occur in the 2,000 replications for the specific Center.

TABLE 3-7: FREQUENCY DISTRIBUTIONS FOR SIMULTANEOUS PRIMARY SERVICE OUTAGES IN EACH FDEP SYSTEM

CENTER	BACK-UP PORTS, P	MEAN SIMUL-TANEOUS COMBINED SERVICE OUTAGES MCO(P)	MEAN TIME OF COMBINED SERVICE OUTAGES PER SITE PER DAY MTO(P) (seconds)	EXTREME OUTAGES PER SITE PER DAY $\bar{s}(0.001, P)$ (seconds)
New York	0	.228	624.	4310.
	1	.133	363.	2508.
	2	.083	226.	1561.
	3	.042	115.	794.4
	4	.015	39.8	274.9
	5	.004	11.0	76.0
	6	.002	4.11	28.4
	7	.001	1.37	9.5
Indianapolis	0	.139	572.	3951.
	1	.075	307.	2121.
	2	.042	171.	1181.
	3	.024	98.7	681.8
	4	.011	43.2	298.4
	5	.001	4.11	28.4
	6	---	---	---
	7	---	---	---

TABLE 3-8: EXPECTED COMBINED SERVICE OUTAGES vs. NUMBER OF BACK-UP PORTS

SECTION 4

IMPACT ON NADIN

4.1 INTRODUCTION

The analysis of the impact of FDEP on NADIN served two purposes within this study. First, such impacts had to be identified in order to determine the costs associated with the integration of FDEP into NADIN. This analysis was thus a major step in the comparative evaluation of FDEP communications support strategies. Second, itemization of these impacts will facilitate subsequent specifications of required NADIN enhancements, should it be desired to integrate FDEP into NADIN.

4.1.1 Summary of Findings

If FDEP service is integrated into NADIN, consideration should be given to the inclusion of a local switching function at each concentrator, to switch FDEP messages directly to the collocated NAS 9020 computer or to the appropriate remote FDEP sites. This is feasible because FDEP messages from within the area controlled by one ARTCC are never directed to sites outside that area.

Whether the local switching function is implemented or not, FDEP will have the following impact on NADIN:

(1) Each NADIN concentrator must provide from 6 to 10 ports for FDEP circuits to remote sites.

(2) Each NADIN concentrator must provide ADCCP link control to the FDEP circuits.

(3) Each NADIN concentrator must maintain address/routing tables for FDEP sites.

If the local switching function is not provided, FDEP will, in addition, have the following impact on NADIN:

(4a) The average NADIN concentrator will have to process about three times the peak-hour message traffic envisioned without FDEP; for the busiest system, this will mean the addition of about 6000 peak-hour messages.

(5a) The NADIN switches will have to process about twice the peak-hour message traffic envisioned without FDEP and about 2.4 times that envisioned should only one switch be operational; for the latter case, each switch would have to handle over 30,000 FDEP messages during the peak-hour.

(6a) The average concentrator-to-switch link would have to handle about twice the peak-hour message traffic envisioned without FDEP; for the link with the greatest FDEP traffic, this would mean the addition of about 1000 bits per second (b/s) or a total of about 1500 b/s, well within the 4800 b/s line capacity.

If the local switching function is provided, FDEP will, in addition to the three items specified originally, have the following impact on NADIN:

(4b) Each NADIN concentrator will have to be able to recognize FDEP messages and route them to the appropriate destination.

(5b) The average NADIN concentrator will have to be able to process only about twice the peak-hour message traffic envisioned without FDEP; for the busiest system, this will mean the addition of about 3000 peak-hour messages.

(6b) There would be no impact on the NADIN switches or the concentrator-to-switch links.

This section elaborates on these findings and presents the analysis upon which they are based.

4.1.2 General Approach

Three general areas of possible FDEP impact on NADIN were identified and analyzed. These are:

- NADIN concentrator ports required to support FDEP,
- special concentrator functions required to support FDEP, and
- NADIN backbone network load imposed by the integration of FDEP.

The analysis of concentrator port requirements was carried out as part of the line layout analysis. The results obtained are included in Section 3.4, above.

The other two areas of NADIN impact are effected by the specific manner in which FDEP messages will be handled by NADIN. Two modes of operation for FDEP message processing have been identified. These are:

- Standard NADIN Mode — Under this mode, all messages (input and output) will be forwarded from the concentrator to the NADIN switch and from the switch back to the concentrator, before being directed to their destinations.
- Local Switch Mode — Under this mode, any message arriving at the concentrator through ports used for FDEP messages will first be processed to determine if it is in fact an FDEP message. If so, the message will be routed for direct transmission to its destination. If not, the message will be routed to the NADIN switch.

It should be noted that both modes can handle non-FDEP messages received from the RCUs. This study did not, however, address the requirement for such a capability, nor did it consider the impact of such non-FDEP messages on NADIN.

4.2. SPECIAL CONCENTRATOR FUNCTIONS

If FDEP systems are to be integrated into NADIN, the NADIN concentrator firmware and/or software must be enhanced to accommodate the following functions:

- provide ADCCP link control for the local access FDEP circuits;

- maintain address/routing tables for FDEP sites; and

- if the local switch mode is implemented, process messages so as to identify FDEP messages and route them directly to their destination ports, rather than through the NADIN switch.

These functions vary somewhat with the specific mode of operation and will also vary between input messages (from remote FDEP sites to NAS 9020 computer) and output messages (from NAS 9020 computer to remote FDEP sites). These variations are outlined below.

4.2.1 Standard NADIN Mode Functions

4.2.1.1 Input Message Functions

Under the standard NADIN operating mode, the NADIN concentator must perform the following functions for FDEP input messages:

(1) serve as the primary station under the ADCCP link protocol, including polling remote sites and acknowledging transmissions acceptably received;

(2) check for parity and format errors in transmissions received from remote sites, implementing appropriate recovery procedures when necessary (as provided under the ADCCP protocol),

(3) buffer messages acceptably received from remote sites;

(4) add overhead and other special information required by NADIN backbone protocol, including address for NAS 9020 computer;

(5) transmit messages to NADIN switch, retransmitting message when necessary;

(6) check for parity and format errors when messages are received from the switch, implementing appropriate recovery procedures when necessary (as provided under the NADIN backbone protocol);

(7) buffer messages acceptably received from the switch;

(8) determine addressee (NAS 9020 computer for all input FDEP messages) and associated concentrator output port;

(9) implement NADIN/NAS protocol, including ASCII to EBCDIC code conversion and the addition of appropriate overhead; and

(10) transmit messages to the NAS 9020 computer, retransmitting messages when necessary.

4.2.1.2 Output Message Functions

Under the standard NADIN operating mode, the NADIN concentrator must perform the following functions for FDEP output messages:

(1) check for parity and format errors in messages received from the NAS 9020 computer, implementing appropriate recovery procedures when necessary (as provided under the NADIN/NAS protocol);

(2) buffer messages acceptably received from the computer;

(3) convert message code from EBCDIC to ASCII;

(4) add overhead and other special information required by NADIN backbone protocol, including address(es) of destination RCUs;

(5) transmit messages to NADIN switch, retransmitting messages when necessary;

(6) check for parity and format errors when messages are received from the switch, implementing appropriate recovery procedures when necessary (as provided under the NADIN backbone protocol);

(7) buffer messages acceptably received from the switch;

(8) determine addressee(s) and associated concentator output port(s);

(9) implement ADCCP protocol, including the addition of appropriate overhead and the selection for output transmission of the appropriate RCU(s); and

(10) transmit messages to the appropriate RCU(s), retransmitting messages when necessary.

4.2.1.3 General Functions

Under the standard NADIN operating mode, the NADIN concentrator must also perform the following functions for general FDEP operations:

(1) perform the general link control functions under ADCCP for the FDEP local access circuits;

(2) notify RCUs when input buffers are full; and

(3) recoginze the loss of primary connections and the establishment (and discontinuance) of dial back-up connections, notifying the NADIN switch of port changes.

4.2.1.4 Unique Functions

Most of the concentrator functions listed above are standard functions of the NADIN concentrator, implemented for most NADIN services. Those that are somewhat unique to FDEP are:

(1) maintenance of FDEP port address tables (output functions 3 and 8, general function 3);

(2) implementation of ADCCP protocol for FDEP circuits (input functions 1 and 2, output functions 9 and 10, general function 1 and 2).

4.2.2 Local Switch Mode Functions

4.2.2.1 Input Message Functions

Under the local switch operating mode, the NADIN concentrator must perform the following functions for FDEP input messages:

(1) serve as the primary station under the ADCCP link protocol, including polling remote sites and acknowledging transmissions acceptably received;

(2) check for parity and format errors in transmissions received from remote sites, implementing appropriate recovery procedures when necessary;

(3) buffer messages acceptably received from remote sites;

(4) determine if message is actually an FDEP message (carry out input functions 4 and 5 under standard NADIN mode, if not);

(5) implement NADIN/NAS protocol, including ASCII to EBCDIC code conversion and the addition of appropriate overhead; and

(6) transmit messages to the NAS 9020 computer, retransmitting messages when necessary.

4.2.2.2 Output Message Functions

Under the local switch operating mode, the NADIN concentrator must perform the following functions for FDEP output messages:

(1) check for parity and format errors in messages received from the NAS 9020 computers, implementing appropriate recovery procedures when necessary;

(2) buffer messages acceptably received from the computer;

(3) convert message code from EBCDIC to ASCII;

(4) determine if message is an FDEP message (carry out output functions 4 and 5 under standard NADIN mode, if not);

(5) determine addressee(s) and associated concentrator output port(s);

(6) implement ADCCP protocol, including the addition of appropriate overhead and the selection for output transmission of the appropriate RCU(s); and

(7) transmit messages to the appropriate RCU(s), retransmitting messages when necessary.

4.2.2.3 General Functions

Under the local switch operating mode, the NADIN concentrator must also perform the following functions for general FDEP operations:

(1) perform the general link control functions under ADCCP for the FDEP local access circuits;

(2) notify RCUs when input buffers are full; and

(3) recognize loss of primary connections and the establishment (and discontinuance) of dial back-up connections.

4.2.2.4 Unique Functions

The concentrator functions listed above are, for the most part, a subset of those listed for the standard NADIN operating mode. Thus, the two functions identified as unique to FDEP (Section 4.2.1.4.)—maintenance of FDEP address tables and implementation of ADCCP protocol—are pertinent also to the local switch mode.

This mode does, however, include one additional unique FDEP function. Under the local switch mode, the concentrator must process incoming messages to determine if they

are FDEP messages (input function 4, output function 4). The special logic must then route the message for appropriate processing and transmission directly to the destination, rather than to the NADIN switch.

4.3 BACKBONE LOAD

The addition of FDEP to the original set of NADIN services, without the provision of local switching at the concentrators, would have the effect of:

- almost tripling the number of peak-hour messages that must be processed by the average NADIN concentrator,
- more than doubling the number of peak-hour messages that must be processed by a NADIN switch, and
- more than doubling the traffic on the average concentrator/switch communications link.

If the local switch mode were implemented, the addition of FDEP would:

- almost double the number of peak-hour messages that must be processed by the average NADIN concentrator;
- have no impact on the NADIN switches or concentrator/switch communications link.

These increases in processing and transmission loads appear to be well within planned NADIN capabilities. Even under worst conditions, less than half of the concentrator/switch line capacity would be used.

4.3.1 Concentrator Processing Requirements

If FDEP traffic is added to NADIN, the average NADIN concentrator will be expected to process about 1500 FDEP messages during the peak hour. If the standard NADIN

operating mode is employed, each message will be processed twice—once before it is routed to the NADIN switch and once on its return from the switch. Thus, under that mode, the average concentrator would actually be expected to process the equivalent of 3000 FDEP messages during the peak hour. The busiest FDEP system, that associated with the New York Center, will be expected to process slightly more than twice the average FDEP traffic.

The NADIN specifications estimated that the average concentrator would process 1,545 messages during the peak hour, prior to the integration of FDEP and other enhancements. Thus, the addition of FDEP would essentially double or triple (depending on operating mode employed) the message processing load at the average concentrator.

Table 4-1 shows the estimated FDEP message loads for each concentrator and for the "average" concentrators. These data are based on the message traffic projections shown in Appendix A. The "Local Switch Mode" values reflect each peak-hour message counted once; the "Standard NADIN Mode" values reflect each message counted twice. The "Near-Range" data are based on projections for 1982; the "Long-Range," on projections for 1991. The concentrators in Table 4-1 are grouped, and their data averaged, based on whether they are associated with the West (Salt Lake City) or East (Atlanta) NADIN switch. This grouping is important primarily for the subsequent consideration of the NADIN switch loads.

4.3.2 Switch Processing Requirement

If FDEP traffic is added to NADIN and the standard NADIN operating mode is employed, each NADIN switch must, on the average, process about 15,000 FDEP messages during the peak hour. The Atlanta (East) switch is expected to process about 20 percent more FDEP messages than the average; the Salt Lake City (West) switch, 20 percent less than the average. For those occasions when one switch is down and the other handles all NADIN switching activities, each switch must be capable of processing about 30,000 FDEP messages during the peak hour.

The NADIN specifications estimated that a switch would have to process 14,256 messages during the peak hour if both switches were up, and 21,353 messages if only one were up. Thus, the addition of FDEP (under the standard NADIN mode) would double the normal processing load at each switch and more than double (2.4 times) the load when only one switch is operational.

Table 4-2 shows the estimated message loads for the two switches, for one switch when the other is down (total) and for the "average" switch. These data are an aggregation

of the data in Table 4-1; note, however, that unlike the concentrators under the standard NADIN mode, each FDEP message is processed only once at the switch.

4.3.3 Communications Link Load

If FDEP traffic is added to NADIN without local switching, the average concentrator-to-switch communications link will be expected to handle about 500 bits per second (b/s) of FDEP traffic during the peak hour. The busiest such link, that associated with the New York Center, will be expected to handle about 1000 b/s of such traffic. Under the local switch mode, there would be no FDEP traffic on those links.

Table 4-3 shows the near- and long-range link loads for FDEP traffic associated with the average center, the New York Center, and the Indianapolis Center. These were estimated using:

$$BPS = MPH \times CPM \times OHF \times BPS/SPH$$

where BPS is the link load in bits per second;

MPH is the peak hour messages transmitteed in each direction over the link;

CPM is the mean number of characters per message (100);

OHF is the overhead function, i.e., average number of characters transmitted per message character;

BPC is the number of bits per character (8); and

SPH is the number of seconds per hour (3600).

Thus:

$$BPS = .222 \times MPH \times OHF$$

Values for MPH are based on data shown in Table 4-1 under Standard NADIN Mode. Only half of the "standard NADIN mode" messages are transmitted in each direction, however.

The overhead function, OHF, has been estimated as 1.6, i.e., there will be an additional 60 characters transmitted for every 100 message characters transmitted. This provides for approximately:

- 44 characters of message overhead required by NADIN (see Appendix B);
- 6 characters of ADCCP protocol overhead, plus;
- an average of 10 characters per message for miscellaneous transmissions, including ADCCP zero insertions, retransmitted frames, and supervisory frames.

Thus:

$$BPS = .3556 \times MPH$$

The NADIN specifications estimated that such links would have to carry 36 characters (288 bits) per second of actual messages during the peak hour without FDEP and other enhancements. Assuming the same overhead factor (1.6) for those messages, that link load would be about 461 b/s. Thus the average link with FDEP traffic would have a combined load of about 1000 b/s, well within the 4800 b/s line capacity. Even the link from the New York Center, which has the greatest FDEP load, will require less than half the line capacity.

CONCENTRATOR	Standard NADIN Mode NEAR-RANGE	Standard NADIN Mode LONG-RANGE	Local Switch Mode NEAR-RANGE	Local Switch Mode LONG-RANGE
Albuquerque	1452	1676	726	838
Denver	994	1228	497	614
Fort Worth	3494	4230	1747	2115
Houston	3452	4286	1726	2143
Kansas City	1862	2310	931	1155
Los Angeles	3906	4732	1953	2366
Oakland	3688	4430	1844	2215
Salt Lake City	872	1038	436	519
Seattle	1658	2058	829	1029
WEST AVERAGE	2375	2888	1188	1444
Atlanta	3598	4446	1799	2223
Boston	2180	2720	1090	1360
Chicago	3590	4406	1795	2203
Cleveland	4110	5144	2055	2572
Indianapolis	2314	2950	1157	1475
Jacksonville	1550	1916	775	958
Memphis	1620	2022	810	1011
Miami	2322	2870	1161	1435
Minneapolis	1860	2254	930	1127
*New York	5536	6732	2768	3366
Washington	2526	3112	1263	1556
EAST AVERAGE	2837	3507	1418	1753
OVERALL AVERAGE	2629	3228	1315	1614

*BUSIEST FDEP SYSTEM

TABLE 4-1: PEAK-HOUR FDEP MESSAGE LOAD ON NADIN CONCENTRATORS

SWITCH	NEAR-RANGE	LONG-RANGE
Salt Lake City	10,689	12,994
Atlanta	15,603	19,286
TOTAL	26,292	32,280
AVERAGE	13,146	16,140

NOTE: STANDARD NADIN OPERATING MODE ASSUMED.

TABLE 4-2: PEAK-HOUR FDEP MESSAGE LOAD ON NADIN SWITCHES

LINK: SWITCH-TO-	NEAR-RANGE (b/s)	LONG-RANGE (b/s)
Average Center	478	574
New York Center	984	1,197
Indianapolis Center	411	524

TABLE 4-3: ONE-DIRECTIONAL LOAD ON CONCENTRATOR/SWITCH LINKS DUE TO FDEP TRAFFIC

SECTION 5

COMPARATIVE EVALUATION

5.1. INTRODUCTION

The subtasks described in the preceding sections generated detailed characteristics for the upgraded FDEP service. The final subtask, discussed in this section, used those results to determine the optimal strategy for the communications support of FDEP.

5.1.1 Summary of Findings

Three alternative strategies for the communications support of upgraded FDEP service have been analyzed. The results of that analysis, i.e., the major differences found, are summarized in Table 5-1. These basic alternatives are applicable if NADIN is to be implemented prior to or soon after the FDIO equipment replacement program.

Three additional alternatives have also been analyzed, to reflect the possibility that NADIN may not be implemented until significantly after the FDIO program. Each of these alternatives presumes that basic Alternative 1 (using Central Control Units (CCUs) rather than NADIN concentrators) will be implemented, at least as an interim approach. Table 5-2 summarizes the results of that analysis.

From these results, it can be concluded that:

(1) It will be more economical to integrate FDEP into NADIN, even if CCUs must be procured for interim use.

(2) When integrating FDEP into NADIN, it will be more economical to leave the NADIN concentrators without local switching capability for FDEP messages.

(3) The addition of local switching capability for FDEP messages in the NADIN concentrator would significantly reduce the peak-hour load on NADIN backbone elements at a relatively low additional cost ($60,000).

The detailed analysis that led to these findings, as well as a more detailed discussion of the results, are presented below.

5.1.2 General Approach

This comparison of alternative strategies for supporting upgraded FDEP service was carried out in four major steps:

(1) The first step involved the review of the NADIN and FDIO specifications. This led to the identification of three basic and three conditional alternatives for upgrading FDEP.

(2) The various alternatives identified were then analyzed in depth to determine the major differences involved.

(3) Next, an analysis was conducted to associate costs with the differences identified and thereby obtain comparative costs for the various options.

(4) Finally, the implications of identified differences that had no cost impact were addressed.

5.2. FDEP COMMUNICATIONS SUPPORT ALTERNATIVES

Three basic alternatives are being considered for supporting the upgraded FDEP service. Each involves implementation of the FDIO equipment replacement program; however, only one involves the procurement of CCUs as part of that program. The three alternatives are:

(1) purchase and use CCUs for the interface between the NAS 9020 computers and communications links from remote FDEP facilities,

(2) use NADIN concentrators as initially specified (i.e., without local switching capability) to serve the CCU role,

(3) use NADIN concentrators with local switching capability to serve the CCU role.

These alternatives are meaningful if NADIN becomes operational prior to or shortly after the FDIO program is implemented. If NADIN is not to become operational until significantly after implementation of the FDIO program, the CCUs should be purchased (i.e., basic Alternative 1, above, should be implemented), at least for interim use. There would then be three conditional alternatives:

(1a) Continue to operate FDEP independently of NADIN.

(1b) When NADIN becomes operational, use NADIN concentrators **without** local switching capabilities to functionally replace the CCUs. (Salvage as much value from the CCUs as possible, through use of CCU components for RCUs and PCUs.)

(1c) When NADIN becomes operational, use NADIN concentrators **with** local switching capabilities to functionally replace the CCUs. (Salvage as much value from the CCUs as possible.)

Figure 5-1 reflects the three basic alternatives. In that figure, facilities and communications links that would exist irrespective of the alternative selected are shown with solid lines. Dashed lines are used to indicate features that are unique to one or two of the alternatives.

5.2.1 Implementation Questions

It is assumed (and felt to be highly likely) that both the FDIO and NADIN programs will be implemented in the next few years, essentially as provided for in the referenced specifications. Those specifications leave unanswered four key questions pertinent to the communications support of FDEP services. These are:

- Should the CCUs described in the FDIO specifications be (purchased and) used as the concentrators for FDEP message traffic at ARTCCs, rather than the NADIN concentrators?

- Should local switching capability, especially for FDEP messages, be provided with the NADIN concentrators?

- Should FDEP equipment, especially the RCUs and their links to the ARTCCs, be made available for message traffic other than FDEP?

- Will the NADIN backbone network be operational before the FDIO program is implemented?

5.2.2 Questions Addressed

This study directly addressed the first two questions above: i.e., should the CCUs or the NADIN concentrators be used for FDEP and, if the NADIN concentrators are to be used, should local switching for FDEP messages be provided? The third question, relating to use of FDEP facilities for other types of message traffic, cannot be addressed at this time, since there is no definitive information on the nature of such "other" traffic. The possiblity that some implementation alternatives could accommodate such traffic is addressed, however, since that would be a potential benefit.

The final question is of importance primarily in its effect on the selection of the optimal support alternative. There will be no upgrading of FDEP without implementation of the basic FDIO program. Should NADIN be available before or shortly after the FDIO program is implemented, there is a simple choice between use of either the CCUs or NADIN concentrators for FDEP. If, however, NADIN will not be available until significantly after FDIO, the urgency for upgrading the FDEP service would dictate the procurement of CCUs. There would still be a question, however, as to whether the NADIN concentrator should ultimately replace the CCUs for FDEP communications.

5.3 ANALYSIS OF ALTERNATIVES

Most elements of the alternative FDEP communications support modes are common, as suggested in Figure 5-1. The major differences can be summarized as follows:

- Basic Alternative 1 requires the purchase and installation of two CCUs and 2 GPI adaptors (for the NAS 9020 PAM), including all associated software/firmware, at

each ARTCC. Only FDEP messages are to be handled by this system and such messages are routed directly by the CCU between the NAS 9020 computer and the RCUs.

- Basic Alternatives 2 and 3 require the purchase and installation of up to 10 ports for each NADIN concentrator (to support RCU input/output), plus the software/firmware to support those ports. Both alternatives would facilitate use of FDEP equipment for other than FDEP traffic.

- Basic Alternative 2 causes all traffic to be routed through a NADIN switch, thus requiring concentrators to process each FDEP message twice.

- Basic Alternative 3 requires special software/firmware for the NADIN concentrators to recognize FDEP messages and route them directly to their destinations. Other messages received through ports used for FDEP are routed to the NADIN switch.

- Conditional Alternatives 1a, 1b, and 1c assume that CCUs are purchased. Under Alternatives 1b and 1c, some recovery of CCU costs will be possible.

- Conditional Alternative 1a is essentially the same as basic Alternative 1; there will be no additional direct costs for hardware, software, or firmware. One indirect cost must be considered, however, when comparing this alternative with Alternatives 1b and 1c. This is the future cost of additional RCU and PCU components that must be purchased (i.e., the salvage value of the CCUs).

- Conditional Alternatives 1b and 1c are essentially the same as basic Alternatives 2 and 3, respectively, except for the interim use of CCUs.

The following sections present a more detailed discussion of the unique features of each alternative.

5.3.1 Basic Alternative 1

The use of CCUs as the concentrators for FDEP traffic at ARTCCs is the primary implementation mode addressed by the FDIO program. Under this alternative, two CCUs will be located at each ARTCC, each CCU being capable of handling all FDEP traffic for that Center. Each CCU will be interfaced with the NAS 9020 computer at the Center through its own pair of GPO/GPI adaptors in the NAS 9020 PAM. Only one CCU will be on-line at one time. Should the on-line CCU go down, the NAS 9020 logic will recognize this and automatically bring the other CCU on-line.

This alternative differs from the other alternatives in the following respects:

5.3.1.1 Hardware

- Two CCUs must be purchased, installed, and maintained at each of the 20 ARTCCs.

- Two GPI adaptors for the NAS 9020 PAM must be purchased and installed at each of the 20 ARTCCs. (No new GPO adaptors are required, since the FDIO program will free a large number that are currently used for FSPs at each Center.)

5.3.1.2 Software/Firmware

- All CCU software/firmware must be developed, including the adaptation of protocols for the CCU/RCU and CCU/NAS 9020 interfaces.

- New software/firmware is also required for the NAS 9020 to support FDEP GPO/GPI adaptors, including that required to effect switch-over in the event of CCU outage.

5.3.1.3 Operations

- Only message traffic to or from FDEP sites within the region controlled by a single ARTCC can be handled by this alternative.

- The NADIN backbone network will not be used for FDEP traffic under this alternative.

5.3.2 Basic Alternative 2

The use of the NADIN concentrator to interface the lines from remote FDEP sites with the NAS 9020 computer would eliminate the need for CCUs. Under this alternative, the NADIN concentrator would treat FDEP messages in the same manner as other NADIN traffic, routing each message through the NADIN switch.

This alternative differs from the other alternatives in the following respects:

5.3.2.1 Hardware

- Up to 10 ports for terminating lines from remote FDEP sites must be added to each of the 20 NADIN concentrators. (The concentrator-to-NAS 9020 link will be the same one used for Service B.)

- There could potentially be requirements for additional buffers and CPU capacity in NADIN concentrators and switches, and for additional line capacity on the concentrator-to-switch links, to handle the additional traffic imposed by FDEP. The relatively low utilization of NADIN capacity, by services initially designated for incorporation, make such requirements unlikely. Such requirements should be reviewed after the initial NADIN capacities are defined (by the NADIN contractor) and decisions concerning other NADIN enhancements are finalized.

5.3.2.2 Software/Firmware

- Software/firmware will be required for NADIN concentrators to adapt the ADCCP protocol (already included) for the links to remote FDEP sites.

- General software/firmware to support the new ports will also be required for the NADIN concentrators.

5.3.2.3 Operations

- This alternative can accept any type of NADIN-compatible message traffic to or from remote FDEP sites.

- All messages (including FDEP) will be routed from the NADIN concentrator to the NADIN switch prior to being routed to their destinations.

- All FDEP messages will be processed twice by the NADIN concentrator — once to effect routing to the NADIN switch and once to effect routing to their destinations.

5.3.3 Basic Alternative 3

The addition of a local switching capability (at least for FDEP messages) to each NADIN concentrator combines some of the unique benefits of Alternatives 1 and 2. Under Alternative 3, no CCUs are required (as with Alternative 2) and FDEP imposes no load on the NADIN switch or the concentrator-to-switch links (as with Alternative 1). In addition, this alternative reduces the load on the NADIN concentrators (relative to Alternative 2), since each message would be processed only once.

This alternative differs from the other alternatives in the following respects:

5.3.3.1 Hardware

- As with basic Alternative 2, up to 10 ports must be added to each NADIN concentrator for FDEP service.

- As with basic Alternative 2, there could potentially be requirements for additional buffers and CPU capacity, but only in the NADIN concentrators, and then no more than half that required for Alternative 2.

5.3.3.2 Software/Firmware

- As with basic Alternative 2, software/firmware will be required to adapt ADCCP and to generally support the new concentrator ports.

- This alternative will, in addition, require special software/firmware to implement the local switching feature.

5.3.3.3 Operations

- This alternative will accept any type of NADIN-compatible message traffic to or from the remote FDEP sites.

- FDEP messages will be routed directly to their destinations, rather than through the NADIN switches.

5.3.4 Conditional Alternatives 1a, 1b, and 1c

Alternatives 1a, 1b, and 1c will, in the long range, look and operate like basic Alternatives 1, 2, and 3, respectively. They differ from their basic-alternative counterparts primarily with respect to their relative costs.

These alternatives are appplicable only if the FDIO program is to be implemented significantly in advance of NADIN. This condition would dictate the implementation of basic Alternative 1 for the short range support of FDEP. Thus the costs associated with Alternative 1 would apply equally to all three conditional alternatives.

Alternative 1a, under which basic Alternative 1 is retained for the long range support of FDEP, involves no additional direct cost. It does, however, involve a significant indirect cost. Under Alternatives 1b and 1c, the CCUs purchased for interim use will no longer be required, and so can be salvaged. Specifically, CCU components can be used as replacement parts for RCUs and PCUs, or in the fabrication of new RCUs and PCUs. Thus, over a period of time Alternative 1a will require greater expenditures for RCUs and PCUs than Alternatives 1b and 1c. This added expenditure for Alternative 1a will be equal to the salvage value of the CCUs.

5.4 COST COMPARISONS

The relative costs of the three basic alternatives for supporting FDEP have been estimated to be:

- $142,000 for Alternative 2, involving use of the NADIN concentrators without local switching,
- $202,000 for Alternative 3, involving use of the NADIN concentrators with local switching, and
- $468,000 for Alternative 1, involving use of the CCUs.

These costs represent expenditures in addition to those that would be required for the FDIO and NADIN programs irrespective of the basic alternative selected.

The relative costs of the three conditional alternatives have been estimated to be:

- $610,000 for Alternative 1b, involving use of the NADIN concentrators without local switching,
- $670,000 for Alternative 1c, involving use of the NADIN concentrators with local switching, and
- $729,000 for Alternative 1a, involving continued use of CCUs.

These costs include the $468,000 associated with the implementation of basic Alternative 1 for interim use.

These results suggest that, if the choice of implementation mode for FDEP were to be made on cost alone:

(1) if NADIN is scheduled to be operational prior to or shortly after the FDIO program, CCUs should not be purchased and the NADIN concentrators **without** local switching capability should be used to fill the CCU roles; and

(2) if NADIN is scheduled to be operational significantly after the FDIO program (and hence CCUs are purchased, at least for interim use), the functions of the CCUs should be transferred to the NADIN concentrators **without** local switching capability and CCU components should be salvaged for the repair or fabrication of RCUs and PCUs.

5.4.1 Cost Analysis

Costs associated with the basic FDEP communications support alternatives were determined by estimating only the costs for features that were different among the alternatives. Thus the basic costs for the FDIO and NADIN programs were not considered. Costs associated with the conditional alternatives were derived from the costs determined for the basic alternatives.

Not all of the differences among the alternatives (detailed in Section 5.3) can be expressed in terms of cost at this point in the development of the two programs. Consideration of such differences is presented later, in Section 5.5.

5.4.1.1 Assumptions

In determining the costs of the various alternatives, the following assumptions were used:

(1) All major elements of the FDIO program will be purchased, except for the CCUs and CCU software/firmware, regardless of the FDEP implementation alternative selected.

(2) NADIN will be implemented in the form identified as Level I in the NADIN specifications.

(3) Excess capacity initially available in the NADIN backbone network can be used for FDEP at no cost.

(4) If CCUs are purchased in accordance with basic Alternative 1, and if conditional Alternative 1b or 1c is subsequently implemented, components of CCUs can and will be used as modules for RCUs and/or PCUs.

5.4.1.2 Approach

The cost analysis was conducted by first determining costs associated with the three basic alternatives. Those results were then used to determine the costs associated with the three conditional alternatives.

The analysis considered only the differences among the basic alternatives. Thus any expenditure that was common to all three or that would exist regardless of alternative selected was not considered; rather, it was considered a basic cost of implementing the NADIN or FDIO program. The analysis of alternatives in Section 5.3, above, was used as the basis for identifying pertinent differences.

Potential costs, i.e., those associated with requirements for extra NADIN capacity, were not considered. The NADIN (Level I) specifications appear to provide sufficient excess capacity to accommodate FDEP, if no other services are added. Thus the use of that excess capacity is considered free to FDEP (however, see further discussion in Section 5.5).

Only initial (i.e., non-recurring) costs were considered. This resulted from the fact that none of the differences noted involved recurring costs. It was therefore unnecessary to determine life cycle costs as a means of combining initial and recurring costs for comparison purposes.

Costs for the conditional alternatives were obtained primarily through the addition of short and long range communications support costs, which were determined for the basic alternatives. One new cost element was also considered, the difference in future expenditures for RCUs and PCUs, which would be affected by the use of salvaged CCU components in RCUs and PCUs. This added cost of RCUs and PCUs (identified as the "salvage value of CCUs") is applicable only to Alternative 1, which continues to use CCUs.

Cost components associated with the basic alternatives were considered in two major categories—hardware and software/firmware. The former were analyzed by estimating the cost per unit procured; the latter, by estimating the number of instructions required and the average cost per instruction.

5.4.2 Hardware Costs

The analysis of Section 5.3 identified three hardware items that differed among the alternatives—CCUs, PAM adaptors, and NADIN concentator ports.

5.4.2.1 CCUs

Under Alternative 1 (and all three conditional alternatives) each of the 20 ARTCCs will require 2 CCUs. None are required under Alternatives 2 and 3. It has been estimated that each CCU will cost approximately $8,700, including all software/firmware. Further, it

has been estimated that 75 percent of that cost can be salvaged should the CCU role be taken over by NADIN concentrators.

5.4.2.2 PAM Adaptors

Under Alternative 1 (and all three conditional alternatives) each of the 20 ARTCCs will require 2 additional GPI adaptors in the NAS 9020 PAM. No new GPI adaptors are required under Alternatives 2 and 3. Should the CCU role be taken over by the NADIN concentrators, such adaptors would no longer be required; however, there is no salvage value for such adaptors pertinent to FDEP. The cost of each GPI adaptor is approximately $2,000.

5.4.2.3 Concentrator Ports

Under Alternatives 2 and 3 (and 1b and 1c) up to 10 ports will be added to each NADIN concentrator to interface lines from the remote sites. No such ports are required for Alternative 1 (or 1a), since CCU ports serve that function and their cost is included in the overall CCU cost. Previous analysis of FDEP service (See Table 3-6, Section 3) determined *a nationwide requirement for 164 new NADIN concentrator ports. These ports will cost* approximately $500 each.

5.4.3 Software/Firmware Costs

The analysis of Section 5.3 identified five categories of software/firmware requirements that differ among the basic alternatives. These are the requirements associated with (1) CCUs, (2) PAM adaptors, (3) ADCCP, (4) NADIN concentrator ports and (5) local switching. The cost per instruction for each of these requirements is approximately $100.

5.4.3.1 CCUs

The software/firmware costs associated with the CCUs have been included in the hardware cost estimate (see Section 5.4.2.1, above). Thus this component is not treated separately.

5.4.3.2 PAM Adaptors

Software/firmware to manage the FDEP traffic through the GPO/GPI adaptors of the NAS 9020 PAM will be required for basic Alternative 1 (and all three conditional alternatives), but not for Alternatives 2 and 3. It has been estimated that approximately 400 instructions will be required for this function.

5.4.3.3 ADCCP

Adaptation of the ADCCP protocol for FDEP communications between remote sites and the ARTCC will be required for all alternatives. The cost of providing ADCCP in CCUs, however, is already included in CCU cost estimate. This cost component is, therefore, not used for Alternative 1 (or 1a). Since NADIN concentrators will be procured with ADCCP, regardless of the FDEP support strategy selected, only the adaptation of ADCCP for FDEP needs to be considered for alternatives 2 and 3 (and 1b and 1c). This adaptation is estimated to require 400 instructions.

5.4.3.4 Concentrator Ports

Software/firmware for managing FDEP traffic through the NADIN concentrator ports is applicable only to Alternatives 2 and 3 (and 1b and 1c). Ignoring the requirements associated with local switching, this is estimated to require 200 instructions.

5.4.3.5 Local Switching

Software/firmware for local switching is only required for Alternative 3 (and 1c). This is estimated to require 600 instructions.

5.4.4 Cost Summary

The cost components identified above have been tabulated and totaled in Table 5-3 These results indicate that the use of the NADIN concentrator without local switching is most economical approach for supporting FDEP, even if CCUs are purchased for interim use. The relatively high cost associated with CCUs further suggests that commitment to

CCU purchase be avoided, if this can be done without endangering the timely upgrading of FDEP service.

5.5 OTHER CONSIDERATIONS

When differences not related to costs are considered in combination with cost differences, the following are suggested:

(1) Use of NADIN concentrators, rather than CCUs, appears justified by both cost and non-cost considerations, even if CCUs must be purchased for interim use.

(2) The additional benefits obtainable from local switching capabily for NADIN concentrators (at least for FDEP messages) could well be worth the added cost ($60,000) for that capability.

The analysis of Section 5.3 identified two areas of differences among the FDEP support alternatives that could not be measured in terms of cost (at least not at this time). These were:

- the differing loads the alternatives would place on NADIN backbone elements; and

- the ability to use FDEP facilities for other types of messages.

5.5.1 NADIN Backbone Load

NADIN is being designed as an evolving system, with services added and capacities expanded as the need for and economy of such changes are demonstrated. In light of this, the initial implementation of NADIN will contain significant excess capacity. This excess capacity (which has not yet been fully specified) will be paid for even in the highly unlikely event that no new services are ever added.

This analysis of FDEP integration into NADIN represents one of the first considerations of enhancements to the basic NADIN system. There was no way, during the conduct of

this study, to predict what other services would be added or how much of the excess capacity might be consumed by such other services. As a result, this study did not assign any cost for NADIN capacity used by FDEP (under Alternatives 2, 3, 1b, and 1c).

There now appears to be a high likelihood that two services, FDEP and FSAS, will be added soon after NADIN is operational. Separate efforts by NAC are investigating the combined impact of these services on the NADIN backbone network. Preliminary results from those studies suggest that additional NADIN capacity will be required to service both FDEP and FSAS. The amount of added capacity required will depend on whether FDEP local switching is implemented (local switching is not required for FSAS).

Thus, although the integration of FDEP may not in itself require added NADIN capacity, the indirect impact must be considered. In particular, the $60,000 that can be saved by not providing local switching in the NADIN concentrators should be weighed against the added loads on the NADIN backbone elements (see Table 5-1).

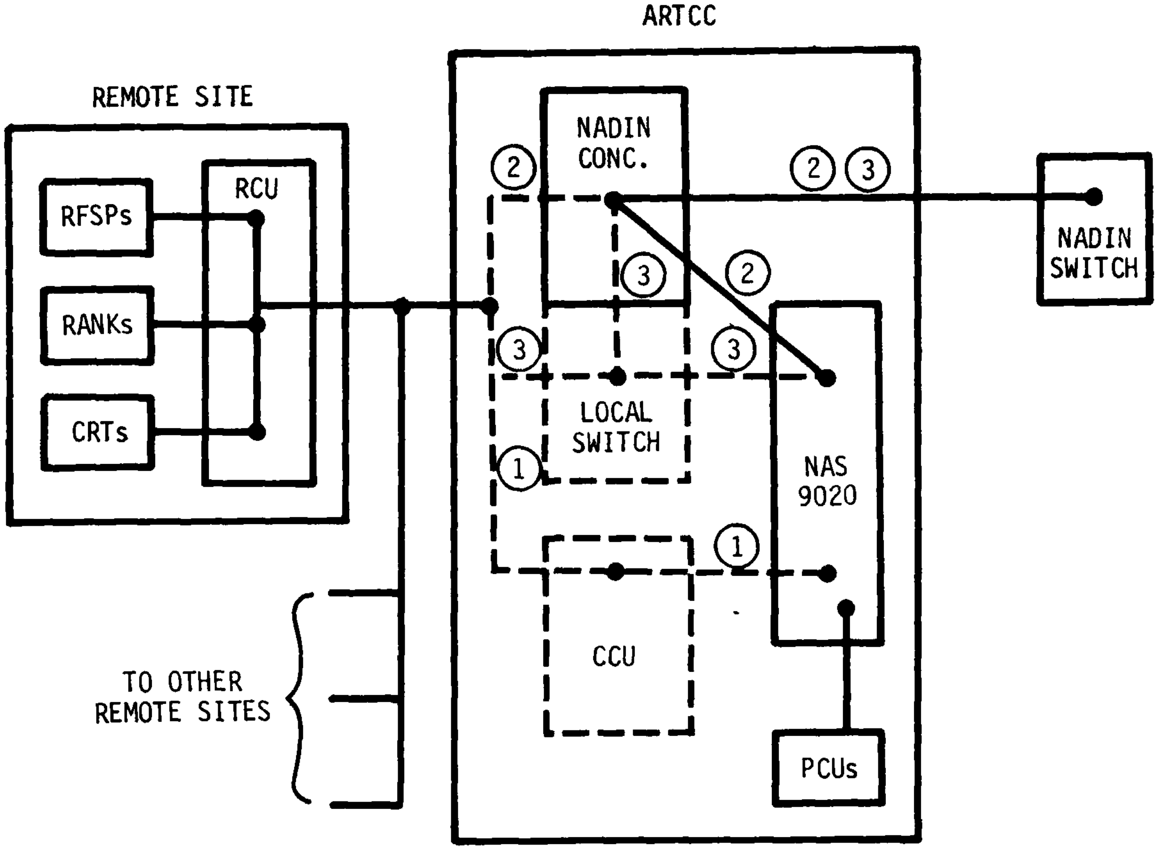
The entire FDEP load on NADIN could, of course, be eliminated by the use of CCUs (Alternative 1). The additional cost, $260,000 ($59,000 for Alternative 1a), coupled with the general disadvantage of having a completely separate network (discussed below) would not appear to be justified by this further reduction of the FDEP load on the NADIN concentrators.

5.5.2 Non-FDEP Message Handling

Although no specific requirements have been identified, it is generally recognized as desirable that FDEP equipment and lines be usable to transmit other types of messages. This is, in fact, one of the general principals behind NADIN—to use common equipment and lines, whenever possible, to provide the various communications services required by FAA, thereby providing high-quality service at reduced cost, maintenance, and general complexity.

All FDEP communications support alternatives involving the NADIN concentrators provide the capability to handle any NADIN-compatible messages directed to or from remote FDEP sites. Minimal software/firmware changes in the RCUs might be required if this potential is to be fully realized. This flexibility could be further extended by connecting non-FDEP terminal equipment located at the remote site to the RCUs.

This potential can be only partially realized through alternatives involving the CCU. In particular, with appropriate software/firmware for CCUs and RCUs, any two (appropriate) terminals could communicate over the system if (1) they are both connected to the same RCU or (2) they are connected to different RCUs, both of which are connected to the same CCU. This capability is not directly addressed by the FDIO program.



LEGEND	
———	COMMON ELEMENTS
– – –	OPTIONAL ELEMENTS
J	MESSAGE PATHS FOR ALTERNATIVE J (J = 1,2,3)

FIGURE 5-1: FDEP COMMUNICATIONS SUPPORT ALTERNATIVES

ALTERNATIVE	CONCENTRATOR USED AT ARTCC	MESSAGE HANDLING FLEXIBILITY	COST[1]	PEAK-HOUR LOAD[2] ADDED TO NADIN
1	CCU	Limited[3]	$468,000	None
2	NADIN, Without Local Switching	Any NADIN-Compatible Messages	$142,000[4]	Conc. - 3,000 Switch - 15,000 Link - 1,500
3	NADIN, With Local Switching	Any NADIN-Compatible Messages	$202,000[4]	Conc. - 1,500 Switch - none Link - none

Notes:

1. Reflects costs of hardware, software, and firmware that is not common to all three alternatives.
2. Average number of peak-hour FDEP messages handled by one NADIN concentrator, by one NADIN switch and, in one direction, by one concentrator-to-switch link (from Section 4).
3. With major software/firmware additions for CCUs, this alternative can provide for general communications between FDEP sites associated with the same ARTCC.
4. These values do not reflect any cost for use of "excess" NADIN capacity.

TABLE 5-1: COMPARISON OF BASIC FDEP IMPLEMENTATION ALTERNATIVES

ALTERNATIVE	CONCENTRATOR USED AT ARTCC: INTERIM	CONCENTRATOR USED AT ARTCC: LONG RANGE	LONG RANGE COST
1a	CCU	CCU	$729,000
1b	CCU	NADIN, Without Local Switching	$610,000
1c	CCU	NADIN, With Local Switching	$670,000

Notes:

- Peak-Hour Load Added to NADIN and Message Handling Flexibility are the same as shown for the basic alternatives (Table 5-1) having the same "Concentrator Used At ARTCC."
- Cost for all three alternatives includes $468,000 to implement basic Alternative 1 for interim use.
- Costs reflect ability to re-use CCU components if CCU use is discontinued.

TABLE 5-2: COMPARISON OF CONDITIONAL FDEP IMPLEMENTATION ALTERNATIVES

AD-A091 580 NETWORK ANALYSIS CORP VIENNA VA F/G 17/2
COMMUNICATIONS SUPPORT FOR FLIGHT DATA ENTRY AND PRINTOUT TERMI--ETC(U)
AUG 80 DOT-FA79WA-4335
UNCLASSIFIED NAC/FR-303B/01 FAA-RD-80-96 NL

2 of 3
AD-A
091580

COST COMPONENTS	UNIT COST	QUANTITY	COMPONENT COSTS FOR BASIC ALTERNATIVES 1	2	3
Hardware:					
CCUs (including all software/firmware)	$8,700	40	$348,000	-------	-------
PAM Adaptors	2,000	40	80,000	-------	-------
Concentration Ports	500	164	-------	$ 82,000	$ 82,000
Software/Firmware Associated with:	$ 100/ instr.				
PAM Adaptors		400	40,000	-------	-------
ADCCP		400	-------	40,000	40,000
Concentrator Ports		200	-------	20,000	20,000
Local Switching		600	-------	-------	60,000
TOTAL			$468,000	$142,000	$202,000

	COSTS FOR CONDITIONAL ALTERNATIVES 1a	1b	1c
Short Range Cost	468,000	468,000	468,000
Long Range Additions	-------	142,000	202,000
Salvage Value of CCUs	261,000	-------	-------
TOTAL	$729,000	$610,000	$670,000

TABLE 5-3: COSTS OF FDEP IMPLEMENTATION ALTERNATIVES

APPENDIX A

FDEP MESSAGE TRAFFIC PROJECTIONS

A.1 PURPOSE AND SCOPE

This appendix presents estimates of FDEP message traffic volumes developed for this study. It also describes the model developed to generate those esitmates. Such estimates were needed as part of the requirements analysis for FDEP communications. Since such estimates are not directly available, this model uses FAA forecasts of air traffic (more specifically, forecasts of instrument operations) at pertinent FDEP installations to deduce the expected numbers of messages transmitted over the FDEP System.

A.2 BASIC CONCEPTS AND DEFINITIONS

A.2.1 General

The FDEP message traffic model considers only the FDEP installations involved in the FDIO equipment replacement program; i.e., those whose communications with the NAS 9020 computer will be interfaced by a concentrator — the Central Control Unit (CCU) or the NADIN concentrator — at the Air Route Traffic Control Center (ARTCC, also referred to as the Center). Such an FDEP system is illustrated in Figure A-1. The message traffic of interest is that between the Remote Control Unit (RCU) at each remote installation and the Center's concentrator.

The nature of the communications links, although of major concern in the overall study, is of no direct interest to the model. Thus, the RCU-to-concentrator links may be point-to-point or multipoint, and the concentrator-to-computer link may or may not involve a NADIN switch.

A.2.2 Remote Installations

A remote FDEP installation is generally an airport, with or without an approach control facility, or a separate approach control facility. Approach control facilities include TRACONs, Common IFR Rooms, Air Force RAPCONs and Navy RATCFs. For convenience in discussions, the term TRACON will be used here to refer to any such facility.

More specifically, a remote FDEP installation will be considered to be the collection of facilities supported by single RCU. Thus if one RCU supports all FDEP equipment at an airport tower and the adjacent TRACON, one remote installation is involved. If, on the other hand, two RCUs are required to support FDEP equipment in one Common IFR Room, two remote installations are involved.

In addition to the existence of replacement FDEP equipment, the model also requires knowledge of the existence of two other services at an installation:

- Automated Radar Terminal System (ARTS), and

- Terminal Control Area (TCA) or Stage III of expanded area radar service.

The importance of this information to the model will be discussed later.

A.2.3 FDEP Messages

The FDEP System has been designed primarily for the transmission of approved flight plans and flight progress messages between the NAS 9020 computer and air traffic controllers. The number of such messages, which are referred to here as basic FDEP messages, is directly related to the number of IFR flights that arrive at, depart from or overfly an FDEP installation. The model primarily reflects this relationship.

The FDEP System is also used to transmit some flight plans from the remote installations to the computer. In addition, the integration of FDEP into NADIN will provide the possibility of using FDEP equipment for more general communications to and from air traffic controllers. Although the latter type messages may not be supported by NADIN and FDIO software/firmware, they are considered in the model in a parametric sense. Together with the flight plan submissions, they will be referred to as miscellaneous FDEP messages.

For purposes of the model, *five* categories of FDEP messages are considered — four for the basic messages and one for the miscellaneous messages. These categories are as follows:

M1 - approved IFR flight plans transmitted from the Center to the tower handling the flight's departure — an abbreviated version is transmitted to the associated TRACON,

M2 - flight progress messages transmitted from a tower without ARTS to the Center, when an IFR flight actually departs (when present, ARTS transmits such data directly),

M3 - flight progress messages transmitted from the Center to towers and TRACONs that are to be overflown by an IFR flight — the TRACON will receive the full message and the tower an abbreviated version,

M4 - IFR flight progress messages transmitted from the Center to the TRACON and tower handling the approach and landing, respectively — the TRACON will receive the full message and the tower an abbreviated version,

M5 - miscellaneous messages.

A.3 MODEL OVERVIEW

As suggested earlier, this model uses forecasts of instrument operations at FDEP installations to deduce the expected number of basic FDEP messages transmitted. In order to include miscellaneous messages and allow a margin for error, the number of messages determined for each installation is increased by a fixed fraction.

The translation from instrument operation counts to basic message counts requires, for each FDEP installation, estimates of peak-hour instrument operations broken out into IFR arrivals, departures and overflights. The major data source available — FAA's Terminal Area Forecasts, Fiscal Years 1980-1991 — provides annual forecasts of total instrument operations. In addition to IFR arrivals, departures and overflights, these counts include IFR separation to non-IFR flights. These latter operations, which have no associated FDEP messages, can occur only at airports with TCA or Stage III radar service.

In order to use the forecast data, the following processing is thus necessary:

- The total instrument counts must first be reduced by the operations associated with non-IFR flights.

- The remaining operations must be broken out into arrivals, departures and overflights.

- The resulting annual counts must be translated into peak-hour counts.

Once the instrument operations have been processed as suggested above, associated basic message counts can be estimated by use of the message definitions in Section A.2.3.

A.4 ASSUMPTIONS

- The FDEP replacement equipment described in the preliminary FDIO specifications will be purchased and installed at the sites tabulated later in this Appendix by the end of FY 1983.

- Whenever a basic FDEP message is to be sent to both the tower and TRACON at one remote installation, only a single message is transmitted from the Center's concentrator to the RCU. The RCU will provide for appropriate processing and distribution.

- Whenever a basic FDEP message is to be sent to both a tower and TRACON at separate remote installations, two messages are transmitted from the Center, one to each RCU.

- The only facility that will require more than one RCU during the period of interest (through 1991) will be the New York Common IFR Room, which will require two RCUs. Each RCU at that facility is assumed to handle half of the total message traffic.

- TCA or Stage III radar service will be available only to those airports that had such service at the end of FY 1979. (This assumption is used due to data limitations, but serves as a conservative estimate.)

- ARTS will be available only at those airports projected to have such equipment delivered by January 1981. (This assumption, also, is used due to data limitations, and serves as a conservative estimate.)

- The fractional breakout of instrument operations, into arrivals, departures, overflights and IFR separation of non-IFR flights, will remain essentially constant for each installation considered. Further, the number of IFR arrivals and departures are assumed to be approximately equal at each installation.

A.5 MODEL DETAILS

A.5.1 Input Data and Parameters

- Identification of FDEP installations to receive the replacement equipment; these will be indexed by I.

- AOPS(I,Y) - the total number of instrument operations (actual or forecast) for installation I in year Y.

- FIFR(I) - the average fraction of instrument operations at installation I that involve arrivals, departures or overflights of IFR flights.

- FOF(I) - the average fraction of IFR-flight instrument operations at installation I that involve overflights.

- FPK - the average fraction of annual instrument operations that occur during a peak operations hour.

- MAO - the average number of FDEP messages transmitted from the center to an installation for each IFR arrival or overflight at that installation (reflecting periodic updates of that flight's progress).

- CARTS(I) - a code indicating if installation I has ARTS; this code is set to 0 if ARTS is present, to 1 otherwise.

- RMB - the average ratio of miscellaneous FDEP messages to basic FDEP messages at any FDEP installation.

A.5.2 Calculations

NPOPS(I,Y)	=	number of peak-hour IFR operations at installation I in year Y
	=	AOPS(I,Y) x FIFR(I) x FPK
NPOF(I,Y)	=	number of peak-hour IFR overflights at installation I in year Y
	=	NPOPS(I,Y) x FOF(I)
NPAD(I,Y)	=	number of peak-hour IFR arrivals <u>or</u> departures at installation I in year Y
	=	NPOPS(I,Y) x $\left[1.0 - \text{FOF(I)} \right]$/2
MPOF(I,Y)	=	number of peak-hour FDEP messages transmitted to installation I in year Y, related to IFR overflights (message type M3)
	=	NPOF(I,Y) x MAO
MPAR(I,Y)	=	number of peak-hour FDEP messages transmitted to installation I in year Y, related to IFR arrivals (message type M4)
	=	NPAD(I,Y) x MAO
MPDP1(I,Y)	=	number of peak-hour FDEP messages transmitted <u>to</u> installation I in year Y, related to IFR dpartures (message type M1)
	=	NPAD(I,Y)

MPDP2(I,Y)	=	number of peak-hour FDEP messages transmitted <u>from</u> installation I in year Y, related to IFR departures (message type M2)
	=	NPAD(I,Y) x CARTS(I)
MTOP(I,Y)	=	the total number of basic FDEP messages transmitted to or from installation I during the peak hour in year Y
	=	MPOF(I,Y) + MPAR(I,Y) + MPDP1(I,Y) + MPDP2(I,Y)
MMIS(I,Y)	=	the expected number of miscellaneous messages transmitted to or from installation I during the peak hour in year Y
	=	RMB x MTOT(I,Y)
INTRF(I,Y)	=	the expected number of peak-hour FDEP messages transmitted <u>to</u> installation I in year Y.
	=	MPOF(I,Y) + MPAR(I,Y) + MPDP1(I,Y) + MMIS(I,Y)/2
OUTTRF(I,Y)	=	the expected number of peak-hour FDEP messages transmitted <u>from</u> installation I in year Y
	=	MPDP2(I,Y) + MMIS(I,Y)/2

A.5.3 Simplifications and Approximations

In evaluating the above expression, the following were used:

FPK = .00035; this factor has proved generally valid in other applications for the FAA.

MAO	=	2.0; this factor was suggested by AAT personnel.
RMB	=	.2; this factor has arbitrarily been selected to provide a margin for error.

A.6 DATA BASE

The tables on pages A-12 through A-31 present input data used to implement the model. Some of the data were based on computer printouts and other unpublished sources. The sources of each data item is indicated below.

Installations - (**CITY, STate, LOCation ID, AIRPORT**) - Unofficial lists of installations, projected to receive FAA-operated FDEP replacement equipment or to have FAA-operated FDEP facilities established, were provided by FAA.

ARTS - Identification of facilities having ARTS was obtained from the ATS Fact Book [6]. This information was supplemented by the (unofficial) ARTS II Schedule Status tables, provided by FAA, which indicated facilities projected to have such service by January 1981. Entries in the tables that follow indicate whether ARTS is available or scheduled (Y) or is not (N).

FOF & FIFR - Breakouts of instrument operations in FY 1979, including overflights and Stage III operations at each FAA installation, were obtained from computer listings provided by FAA (similar data from previous years have been published [7]). Those data were used to calculate FOF, the fraction of IFR operations involving overflights, and FIFR, the fraction of all instrument operations that related to IFR flights.

AOPS - Forecasts of total annual instrument operations at each installation were obtained from Terminal Area Forecasts [8]. Values for 1983, 1987 and 1991 are shown in the tables.

Notes - For some installations, data was not available, or available data was not felt pertinent for use in the model. Such installations are identified by entries in the NOTES column, referencing the specific discussion below:

A. These installations are separate TRACONs or common IFR rooms and so will not generally send FDEP messages to the center concerning IFR flight departures (i.e., no type M2 messages). For purposes of the model, all such facilities are, therefore, treated as if they had ARTS.

B. Forecast data, and in some cases current data, were not available for these military installations. Values typical of IFR-flight instrument operations at other military installations were thus used. As a result, FIFR was set to 1.0 for all such installations, even if current data suggests a different value. If current data were not available for estimating FOF, that value was set to .2, a value typical of other military installations.

C. Comparison of current (1979) and forecast data for these installations suggests there is some incompatibility. Specifically, it appears that the forecast data does not include Stage III instrument operations, while the current data does. To avoid underestimating future operations (and message traffic), FIFR was set to 1.0 for these installations.

A.7 PROJECTIONS

The tables on pages A-32 through A-51 present the results of applying the FDEP message traffic model discussed in the preceding sections of this appendix. A separate table is presented for each ARTCC (Center), ordered alphabetically by Center name. The traffic is shown separately for each FDEP site associated with each Center and for the Center as a whole.

These tables specifically include:

CENTER: the city generally used to identify the location of the Center (and the code used to reference the Center);

LOCation ID: the code used to reference the specific remote site;

CITY & STate: the location of the site;

STATUS: the year in which replacement FDEP equipment is projected to be installed at the site;

IN-TRF: the number of FDEP messages expected to be received during the peak hour at the site from the Center (for near-, mid-, and long-range time frames);

OUT-TRF: the number of FDEP messages expected to be transmitted during the peak hour from the site to the Center.

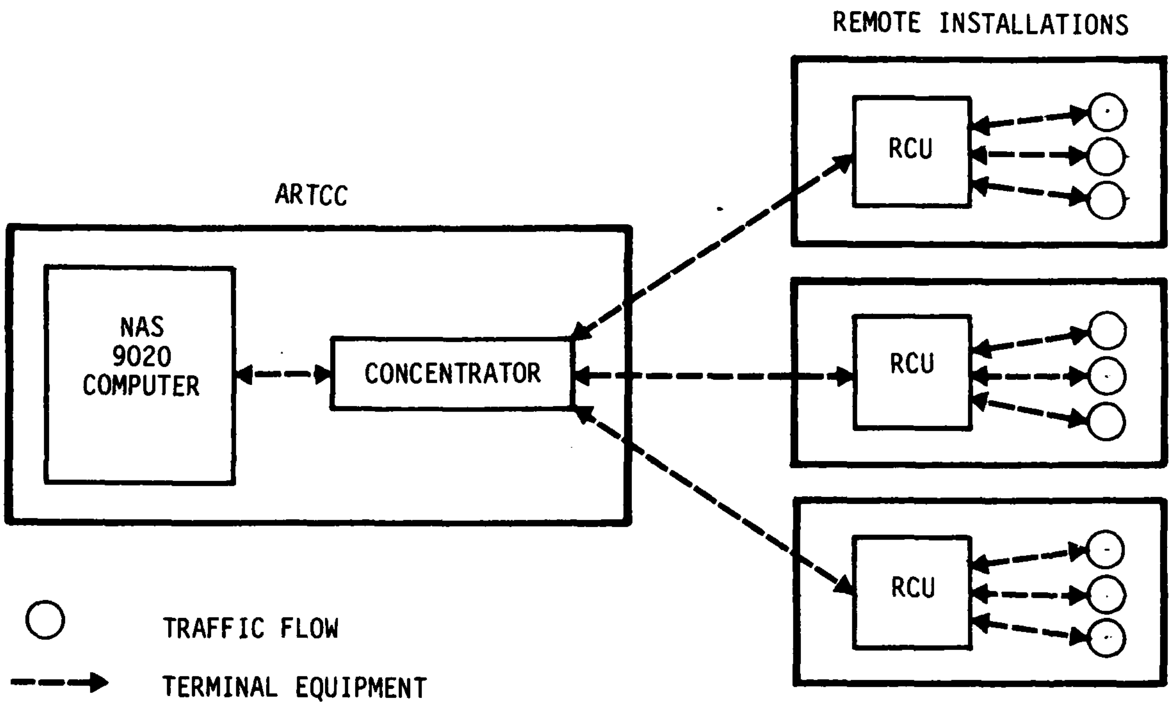


FIGURE A-1: FDEP TRAFFIC FLOW

CENTER : ALBUQUERQUE (ZAB)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
ALBUQUERQUE	NM	ABQ	INTERNATIONAL	Y	0.03	0.48	286	326	357	
ROSWELL	NM	ROW		N	0.18	1.00	21	23	25	
AMARILLO	TX	AMA		N	0.07	1.00	84	94	101	
EL PASO	TX	ELP		Y	0.04	0.50	195	217	241	
PHOENIX	AZ	PHX	SKY HARBOR	Y	0.00	0.47	438	474	478	
PHOENIX	AZ	P90	(TRACON)	Y	0.01	0.65	545	594	629	A
TUCSON	AZ	TUS	INTERNATIONAL	N	0.00	1.00	62	59	60	
TUCSON	AZ	DMA	DAVIS-MONTH. AFB	Y	0.03	0.47	279	296	314	

CENTER : ATLANTA (ZTL)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
BIRMINGHAM	AL	BHM		Y	0.11	0.75	268	302	331	
MONTGOMERY	AL	MGM	DONNELLY FIELD	N	0.20	0.67	164	185	203	B
MONTGOMERY	AL	MXF	MAXWELL AFB	Y	0.20	1.00	120	130	145	
ATLANTA	GA	FTY	CHARLIE BROWN	N	0.00	1.00	47	54	58	
ATLANTA	GA	PDK	DEKALB-PEACHTREE	N	0.00	1.00	50	58	63	
ATLANTA	GA	ATL	HARTSFIELD	Y	0.01	0.94	837	913	986	
COLUMBUS	GA	CSG		N	0.41	0.74	159	181	201	
MACON	GA	MCN		N	0.44	0.73	173	198	229	
WARNER ROBINS	GA	WRB	ROBINS AFB	Y	0.20	1.00	120	130	145	B
ASHVILLE	NC	AVL		N	0.39	0.91	68	80	88	
CHARLOTTE	NC	CLT		Y	0.18	0.69	335	387	429	
GREENSBORO	NC	GSO		Y	0.17	0.61	304	343	378	
WINSTON-SALEM	NC	INT		N	0.00	1.00	36	41	44	
GREER	SC	GSP		Y	0.17	0.83	115	127	141	
BRISTOL	TN	TRI	TRI-CITY	Y	0.25	0.72	108	126	139	
CHATTANOOGA	TN	CHA		Y	0.24	0.67	153	176	195	
KNOXVILLE	TN	TYS		Y	0.19	0.67	191	220	245	

CENTER : BOSTON (ZBW)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
BEDFORD	MA	BED		N	0.00	1.00	29	33	36	
BOSTON	MA	BOS	LOGAN	Y	0.02	0.73	632	721	800	
FALMOUTH	MA	FMH	OTIS AFB	Y	0.01	1.00	80	84	89	
WORCESTER	MA	ORH		N	0.06	1.00	18	21	23	
BANGOR	ME	BGR		Y	0.05	1.00	41	46	50	C
PORTLAND	ME	PWM		Y	0.31	1.00	68	76	84	
WINDSOR LOCKS	CT	BDL		Y	0.14	0.70	273	313	362	
MANCHESTER	NH	MHT		Y	0.03	1.00	38	43	47	
ALBANY	NY	ALB		Y	0.22	0.66	220	253	285	
ROME	NY	RME	GRIFFISS AFB	Y	0.35	1.00	90	98	110	
SYRACUSE	NY	SYR		Y	0.17	0.63	203	232	258	
UTICA	NY	UCA		N	0.00	1.00	74	79	82	
PROVIDENCE	RI	PVD		N	0.00	1.00	44	49	52	
NORTH KINGSTOWN	RI	NCO	QUONSET PT. NAS	Y	0.12	1.00	120	130	145	B
BURLINGTON	VT	BTV		Y	0.14	0.57	163	184	200	

CENTER : CHICAGO (ZAU)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
CEDAR RAPIDS	IA	CID		N	0.19	1.00	130	144	156	
WATERLOO	IA	ALO		Y	0.17	1.00	41	47	54	
CHAMPAIGN	IL	CMI	CHAMP./URBANNA	Y	0.26	1.00	76	85	98	
CHICAGO	IL	MDW	MIMDWAY	N	0.00	1.00	74	85	98	
CHICAGO	IL	ORD	O'HARE	Y	0.00	0.97	1073	1181	1279	
CHICAGO	IL	PWK	PAL-WAUKEE	N	0.00	1.00	40	46	50	
MOLINE	IL	MLI		N	0.15	0.64	133	151	169	
PEORIA	IL	PIA		N	0.18	1.00	74	84	93	C
ROCKFORD	IL	RFD		Y	0.17	0.74	185	201	214	
FORT WAYNE	IN	FWA		Y	0.18	0.64	172	199	222	
SOUTH BEND	IN	SBN		Y	0.17	0.68	212	242	270	
GRAND RAPIDS	MI	GRR		N	0.12	0.58	154	178	196	
KALAMAZOO	MI	AZO		Y	0.25	1.00	73	81	91	
MUSKEGON	MI	MKG		Y	0.14	1.00	38	43	47	
GREEN BAY	WI	GRB		N	0.06	0.71	151	169	184	
MADISON	WI	MSN		N	0.13	0.49	179	204	226	
MILWAUKEE	WI	MKE	MITCHELL FIELD	Y	0.15	0.71	312	352	386	

CENTER : CLEVELAND (ZOB)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
DETROIT	MI	DET	CITY	N	0.00	1.00	66	77	84	
DETROIT	MI	DTW	WAYNE CO.	Y	0.05	0.90	617	683	748	
DETROIT	MI	YIP	WILLOW RUN	N	0.00	1.00	79	94	104	
FLINT	MI	FNT		N	0.27	1.00	77	89	100	C
JACKSON	MI	JXN		N	0.41	1.00	40	47	53	
LANSING	MI	LAN		N	0.25	0.47	174	202	226	
PONTIAC	MI	PTK		N	0.00	1.00	45	53	57	
SAGINAW	MI	MBS		N	0.27	0.72	85	96	104	
BUFFALO	NY	BUF		Y	0.12	0.80	246	278	309	
NIAGARA FALLS	NY	IAG		N	0.00	1.00	20	22	23	
ROCHESTER	NY	ROC		Y	0.17	0.72	237	252	259	
AKRON	OH	CAK	AKRON/CANTON	Y	0.16	0.62	204	234	263	
CLEVELAND	OH	BKL	BURKE-LAKEFRONT	N	0.00	1.00	30	35	38	
CLEVELAND	OH	CGF	CUYAHOGA CO.	N	0.00	1.00	36	42	46	
CLEVELAND	OH	CLE	HOPKINS	Y	0.12	0.79	482	541	603	
MANSFIELD	OH	MFD		Y	0.34	1.00	53	61	70	
TOLEDO	OH	TOL		Y	0.32	0.72	201	232	266	
YOUNGSTOWN	OH	YNG		N	0.18	0.69	108	118	128	
ERIE	PA	ERI		N	0.19	0.77	89	103	119	
PITTSBURGH	PA	AGC	ALLEGHENY CO.	N	0.00	1.00	50	58	64	
PITTSBURGH	PA	PIT	INTERNATIONAL	Y	0.07	0.85	622	705	783	
CLARKSBURG	WV	CKB		Y	0.08	1.00	54	61	68	

CENTER : DENVER (ZDV)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
COLORADO SPRINGS	CO	COS		Y	0.14	0.47	179	201	219	
DENVER	CO	DEN	STAPLETON	Y	0.01	0.74	698	788	867	
DENVER	CO	ARA	ARAPAHOE CO.	N	0.00	1.00	17	20	21	
GRAND JUNCTION	CO	GJT		N	0.00	1.00	15	17	18	
PUEBLO	CO	PUB		Y	0.08	1.00	42	46	51	
FARMINGTON	NM	FMN		N	0.00	1.00	22	24	26	
CASPER	WY	CPR		Y	0.03	1.00	27	30	33	
CHEYENNE	WY	CYS		N	0.12	1.00	31	35	39	

DATA BASE FOR FDEP MESSAGE TRAFFIC MODEL

CENTER : FORT WORTH (ZFW)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
TEXARKANA	AR	TXK		N	0.00	1.00	24	29	32	
MONROE	LA	MLU		Y	0.09	0.85	101	115	124	
SHREVEPORT	LA	SHV	REGIONAL	N	0.09	0.76	185	209	229	
SHREVEPORT	LA	BAD	BARKSDALE AFB	Y	0.20	1.00	120	130	145	B
CLINTON	OK	CSM		N	0.07	1.00	18	20	21	
OKLAHOMA CITY	OK	OKC	WILL ROGERS	N	0.05	0.63	356	400	438	
OKLAHOMA CITY	OK	PWA	WILEY POST	N	0.00	1.00	32	37	40	
OKLAHOMA CITY	OK	TIK	TINKER AFB	Y	0.20	1.00	120	130	145	B
TULSA	OK	TUL	INTERNATIONAL	Y	0.07	0.68	244	279	308	
ABILENE	TX	ABI	MUNICIPAL	N	0.08	1.00	72	76	81	
ABILENE	TX	DYS	DYESS AFB	N	0.20	1.00	120	130	145	B
DALLAS	TX	DAL	LOVE FIELD	N	0.00	1.00	156	175	195	
DALLAS	TX	DFW	DALLAS/FT. WORTH	Y	0.01	0.90	818	902	982	
LUBBOCK	TX	LBB		Y	0.02	0.94	215	226	236	
MIDLAND	TX	MAF		N	0.08	1.00	129	149	162	
SAN ANGELO	TX	SJT		N	0.04	1.00	26	29	30	
TYLER	TX	TYR		N	0.07	1.00	16	19	22	
WACO	TX	ACT		Y	0.21	1.00	32	37	42	

DATA BASE FOR FDEP MESSAGE TRAFFIC MODEL

CENTER : HOUSTON (ZHU)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
MOBILE	AL	MOB		Y	0.18	0.58	170	193	213	
BATON ROUGE	LA	BTR		N	0.29	1.00	84	95	112	
LAKE CHARLES	LA	LCH		Y	0.34	0.85	63	73	83	
NEW ORLEANS	LA	MSY	INTERNATIONAL	Y	0.03	0.75	391	441	491	
NEW ORLEANS	LA	NEW	LAKEFRONT	N	0.00	1.00	39	45	48	
LAFAYETTE	LA	LFT		Y	0.16	0.78	202	243	274	
GULFPORT	MS	GPT		Y	0.26	0.82	76	87	96	
AUSTIN	TX	AUS	MUELLER	N	0.09	1.00	184	211	230	
AUSTIN	TX	BSM	BERGSTROM AFB	Y	0.20	1.00	120	130	145	B
BEAUMONT	TX	BPT		Y	0.24	0.91	111	129	142	
BROWNSVILLE	TX	BRO		N	0.00	1.00	38	42	45	
COLLEGE STATION	TX	CLL		N	0.00	1.00	28	32	36	
CORPUS CHRISTI	TX	CRP		Y	0.09	0.94	147	167	181	
HOUSTON	TX	IAH	INTERNATIONAL	Y	0.02	0.87	689	768	843	
HOUSTON	TX	HOU	HOBBY	N	0.00	1.00	171	190	212	
MC ALLEN	TX	MFE		N	0.00	1.00	16	18	19	
SAN ANTONIO	TX	SAT	INTERNATIONAL	Y	0.05	0.77	403	440	469	

CENTER : INDIANAPOLIS (ZID)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
EVANSVILLE	IN	EVV		Y	0.23	1.00	90	101	115	
INDIANAPOLIS	IN	IND		Y	0.15	0.79	412	474	532	
LAFAYETTE	IN	LAF		N	0.08	1.00	32	38	43	
MUNCIE	IN	MIE		N	0.13	1.00	37	43	48	
TERRA HAUTE	IN	HUF		Y	0.12	1.00	44	52	58	
COVINGTON	KY	CVG	CINCINNATI INT.	Y	0.16	0.83	275	311	347	
LEXINGTON	KY	LEX		N	0.24	0.66	118	137	151	
LOUISVILLE	KY	SDF	STANIFORD	Y	0.16	0.75	270	310	349	
CINCINNATI	OH	LUK		N	0.00	1.00	3	4	4	
COLUMBUS	OH	CMH	INTERNATIONAL	Y	0.13	0.69	425	485	540	
COLUMBUS	OH	OSU	OHIO STATE U.	N	0.00	1.00	25	29	32	
DAYTON	OH	DAY		Y	0.19	0.78	199	224	246	
CHARLESTON	WV	CRW		N	0.19	0.66	147	169	186	
HUNTINGTON	WV	HTS		N	0.13	0.67	73	82	87	

CENTER : JACKSONVILLE (ZJX)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
DOTHAN	AL	DHN		N	0.00	1.00	36	38	40	
DATONA BEACH	FL	DAB		Y	0.21	1.00	95	107	120	
GAINSVILLE	FL	GNV		N	0.00	1.00	27	31	33	
JACKSONVILLE	FL	JAX		Y	0.14	0.81	385	426	465	
PANAMA CITY	FL	PFN		N	0.00	1.00	31	35	39	
PENSACOLA	FL	PNS		Y	0.09	0.47	251	268	281	
TALAHASSEE	FL	TLH		Y	0.26	0.63	117	137	152	
ALBANY	GA	ABY		N	0.15	1.00	29	33	36	
AUGUSTA	GA	AGS		N	0.16	0.89	84	100	112	
SAVANNAH	GA	SAV		Y	0.16	0.58	170	193	212	
CHARLESTON	SC	CHS		Y	0.11	0.69	172	193	208	
COLUMBIA	SC	CAE		Y	0.15	0.50	188	217	241	
FLORENCE	SC	FLO		Y	0.17	1.00	14	16	18	

CENTER : KANSAS CITY (ZKC)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
ALTON	IL	ALN		N	0.00	1.00	22	25	27	
DECATUR	IL	DEC		N	0.04	1.00	32	36	39	
MARION	IL	MWA		N	0.13	1.00	24	27	30	
SPRINGFIELD	IL	SPI		Y	0.21	0.56	150	172	190	
HUTCHINSON	KS	HUT		N	0.09	1.00	27	31	34	
SALINA	KS	SLN		N	0.05	1.00	26	29	32	
WICHITA	KS	ICT		Y	0.03	0.58	243	274	297	
COLUMBIA	MO	COU		N	0.07	1.00	32	36	39	
JOPLIN	MO	JLN		N	0.14	1.00	25	28	31	
KANSAS CITY	MO	MCI	INTERNATIONAL	Y	0.05	0.76	409	461	512	
KANSAS CITY	MO	MKC	MUNICIPAL	N	0.00	1.00	84	95	104	
ST. JOSEPH	MO	STJ		N	0.08	1.00	16	18	19	
ST. LOUIS	MO	STL	LAMBERT FIELD	Y	0.04	0.83	536	602	660	
ST. LOUIS	MO	SUS	SPIRIT OF ST. L.	N	0.00	1.00	29	33	36	
SPRINGFIELD	MO	SGF		Y	0.19	1.00	53	60	68	

CENTER : LOS ANGELES (ZLA)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	AOPS (1000'S) 1987	AOPS (1000'S) 1991	NOTES
BAKERSFIELD	CA	BFL		Y	0.02	1.00	47	54	59	
BURBANK	CA	BUR		Y	0.25	0.55	434	499	559	
CARLSBAD	CA	CRQ	POLOMAR	N	0.00	1.00	33	39	42	
FULLERTON	CA	FUL		N	0.00	1.00	30	35	39	
LONG BEACH	CA	LGB		N	0.00	1.00	100	112	125	
LOS ANGELES	CA	LAX	INTERNATIONAL	Y	0.03	0.85	736	800	858	
MUROC	CA	EDW	EDWARDS AFB	Y	0.52	1.00	146	151	158	
ONTARIO	CA	ONT	INTERNATIONAL	Y	0.00	1.00	97	110	119	
ONTARIO	CA	O40	(TRACON)	Y	0.17	0.71	452	514	583	A
OXNARD	CA	OXR		N	0.00	1.00	36	43	48	
SAN DIEGO	CA	SAN	INTERNATIONAL	N	0.00	0.85	196	214	225	
SAN DIEGO	CA	NKX	MIRAMAR NAS	Y	0.02	0.82	427	458	495	
SANTA ANA	CA	NZJ	EL TORO MCAS	Y	0.20	1.00	120	130	145	B
SANTA ANA	CA	SNA	ORANGE CO.	N	0.00	1.00	142	158	177	
SANTA BARBARA	CA	SBA		Y	0.00	1.00	41	48	53	
SANTA MONICA	CA	SMO		N	0.00	1.00	29	34	37	
VAN NUYS	CA	VNY		N	0.00	1.00	41	47	50	
LAS VEGAS	NV	LAS	MC CARRON	Y	0.01	0.58	452	509	556	

CENTER : MEMPHIS (ZME)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
HUNTSVILLE	AL	HSV		Y	0.25	0.68	155	177	199	
FAYETTEVILLE	AR	FYV		N	0.03	1.00	45	51	57	
FORT SMITH	AR	FSM		N	0.10	1.00	73	87	98	
HOT SPRINGS	AR	HOT		N	0.06	1.00	20	23	26	
LITTLE ROCK	AR	LIT		Y	0.10	0.66	247	280	305	
PINE BLUFF	AR	PBF		N	0.13	1.00	9	11	12	
PADUCAH	KY	PAH		N	0.23	1.00	26	30	33	
CAPE GIRARDEAU	MO	CGI		N	0.18	1.00	19	22	24	
GREENVILLE	MS	GLH		N	0.12	1.00	20	22	24	
JACKSON	MS	JAN		Y	0.10	1.00	94	109	122	C
MERIDIAN	MS	NMM	MERIDIAN NAS	Y	0.10	1.00	84	89	93	
MEMPHIS	TN	MEM		Y	0.04	0.71	454	514	561	
NASHVILLE	TN	BNA		Y	0.08	0.70	288	328	359	

CENTER : MIAMI (ZMA)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	AOPS (1000'S) 1987	AOPS (1000'S) 1991	NOTES
FT. LAUDERDALE	FL	FLL		N	0.00	0.41	435	501	552	
FT. MYERS	FL	FMY		Y	0.02	1.00	46	51	55	
MELBOURNE	FL	MLB		N	0.00	1.00	46	51	56	
MIAMI	FL	MIA	INTERNATIONAL	Y	0.00	0.80	804	884	959	
MIAMI	FL	TNT	DADE-COLLIER	N	0.00	1.00	8	10	10	
ORLANDO	FL	ORL	HERNDON	N	0.00	0.85	50	57	62	
ORLANDO	FL	MCO	INTERNATIONAL	Y	0.13	0.66	308	350	398	
ST. PETERSBURG	FL	PIE		N	0.00	1.00	23	26	28	
SARASOTA	FL	SRQ		N	0.00	1.00	40	44	49	
TAMPA	FL	TPA		Y	0.12	0.69	479	541	599	
WEST PALM BEACH	FL	PBI		Y	0.17	0.44	317	368	411	

CENTER : MINNEAPOLIS (ZMP)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
DES MOINES	IA	DSM		Y	0.11	0.63	201	229	260	
SIOUX CITY	IA	SUX		N	0.08	1.00	44	49	55	
DULUTH	MN	DLH		Y	0.08	1.00	50	54	59	
MINNEAPOLIS	MN	MSP	MINN./ST. PAUL	Y	0.01	0.79	426	482	531	
ROCHESTER	MN	RST		Y	0.09	1.00	45	50	55	C
GRAND ISLAND	NE	GRI		N	0.05	1.00	26	29	32	
LINCOLN	NE	LNK		N	0.08	0.87	178	196	208	
OMAHA	NE	OMA	EPPLEY	N	0.00	1.00	99	110	122	
OMAHA	NE	OFF	OFFUTT AFB	Y	0.06	1.00	120	130	145	B
BISMARK	ND	BIS		Y	0.04	1.00	22	24	26	
FARGO	ND	FAR		N	0.09	1.00	86	94	99	
GRAND FORKS	ND	GFK		N	0.00	1.00	24	27	29	
SIOUX FALLS	SD	FSD		N	0.07	1.00	102	111	117	
LA CROSSE	WI	LSE		N	0.15	1.00	36	42	47	

CENTER : NEW YORK (ZNY)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
WILMINGTON	DE	ILG		N	0.00	1.00	40	45	49	
ATLANTIC CITY	NJ	ACY		Y	0.09	0.59	141	155	167	
NEWARK	NJ	EWR		N	0.01	0.76	290	329	362	
TETERBORO	NJ	TEB		N	0.00	1.00	77	90	100	
TRENTON	NJ	TTN		N	0.00	1.00	27	32	35	
BINGHAMTON	NY	BGM		N	0.18	1.00	60	71	84	
ELMIRA	NY	ELM		N	0.14	1.00	53	59	66	
ISLIP	NY	ISP		N	0.13	1.00	292	309	316	
NEW YORK	NY	N90	(CIFRR-RCU1)	Y	0.07	0.86	672	753	811	A
NEW YORK	NY	N90	(CIFRR-RCU2)	Y	0.07	0.86	672	753	811	A
NEW YORK	NY	JFK	JFK	Y	0.00	0.85	442	485	528	
NEW YORK	NY	LGA	LA GUARDIA	N	0.01	0.74	536	590	661	
WHITE PLAINS	NY	HPN		N	0.06	0.88	173	195	221	
ALLENTOWN	PA	ABE		Y	0.11	0.59	126	140	147	
HARRISBURG	PA	CXY		N	0.12	1.00	137	150	165	
MIDDLETOWN	PA	MDT	HARRISBURG INT.	N	0.00	1.00	44	50	55	
PHILADELPHIA	PA	PHL	INTERNATIONAL	Y	0.05	0.73	633	720	797	
PHILADELPHIA	PA	PNE	NORTH PHIL.	N	0.00	1.00	27	32	35	
READING	PA	RDG		Y	0.17	1.00	29	34	38	
SCRANTON	PA	AVP	WILKES-BARRE	Y	0.22	1.00	81	90	95	
WILLIAMSPORT	PA	IPT		N	0.15	1.00	32	37	41	

CENTER : OAKLAND (ZOA)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
FRESNO	CA	FAT		N	0.04	1.00	113	126	140	
MONTEREY	CA	MRY		N	0.02	1.00	133	146	152	
OAKLAND	CA	OAK	INTERNATIONAL	Y	0.04	1.00	507	571	627	
OAKLAND	CA	090	(CIFRR)	Y	0.05	0.88	818	887	958	A
SACRAMENTO	CA	MCC	MC CLELLAN AFB	Y	0.06	0.63	546	599	654	
SACRAMENTO	CA	SMF	METROPOLITAN	N	0.00	1.00	110	123	137	
SACRAMENTO	CA	SAC	EXECUTIVE	N	0.00	1.00	49	57	62	
SAN FRANCISCO	CA	SFO		N	0.00	0.92	413	455	491	
SAN JOSE	CA	SJC	MUNICIPAL	N	0.00	1.00	128	140	154	
STOCKTON	CA	SCK		Y	0.06	1.00	43	48	52	
RENO	NV	RNO		Y	0.03	1.00	70	77	84	

DATA BASE FOR FDEP MESSAGE TRAFFIC MODEL

CENTER : SALT LAKE CITY (ZLC)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
BOISE	ID	BOI		N	0.02	0.52	232	255	270	
BILLINGS	MT	BIL		N	0.00	1.00	130	142	149	
GREAT FALLS	MT	GFA	MALMSTROM AFB	N	0.00	1.00	120	130	145	B
HELENA	MT	HLN		N	0.00	1.00	10	11	12	
MISSOULA	MT	MSO		N	0.00	1.00	11	12	13	
SALT LAKE CITY	UT	SLC		Y	0.13	0.54	303	343	372	

CENTER : SEATTLE (ZSE)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
EUGENE	OR	EUG		Y	0.00	1.00	56	64	70	
MEDFORD	OR	MFR		N	0.00	1.00	26	30	33	
PENDLETON	OR	PDT		N	0.00	1.00	10	12	13	
PORTLAND	OR	PDX	INTERNATIONAL	Y	0.04	0.62	400	454	502	
EVERETT	WA	PAE		N	0.00	1.00	24	27	29	
MOSES LAKE	WA	MWH		N	0.04	1.00	34	39	42	
PASCO	WA	PSC		N	0.03	1.00	51	58	64	
SEATTLE	WA	BFI	BOEING	N	0.00	1.00	57	67	73	
SEATTLE	WA	SEA	INTERNATIONAL	Y	0.03	0.76	420	474	527	
SPOKANE	WA	SKA	FAIRCHILD AFB	Y	0.04	0.72	164	178	193	
SPOKANE	WA	GEG	INTERNATIONAL	N	0.01	0.69	127	142	151	
TACOMA	WA	TCM	MC CHORD AFB	N	0.18	0.69	151	165	182	
YAKIMA	WA	YKM		N	0.00	1.00	35	41	46	

CENTER : WASHINGTON (ZDC)

CITY	ST	LOCID	AIRPORT (OR FACILITY)	ARTS	FOF	FIFR	AOPS (1000'S) 1983	1987	1991	NOTES
WASHINGTON	DC	DCA	NATIONAL	Y	0.05	0.73	555	602	640	
BALTIMORE	MD	BWI		Y	0.29	0.63	451	519	600	
CAMP SPRINGS	MD	ADW	ANDREWS AFB	N	0.00	0.43	147	150	153	
CHANTILLY	VA	IAD	DULLES(WASH. DC)	Y	0.26	0.76	305	357	407	
LYNCHBURG	VA	LYH		N	0.04	1.00	26	30	33	
NEWPORT NEWS	VA	PHF		N	0.00	1.00	26	28	31	
NORFOLK	VA	ORF		Y	0.06	0.71	359	392	418	
RICHMOND	VA	RIC		Y	0.12	0.66	200	228	250	
ROANOKE	VA	ROA		Y	0.17	0.69	126	142	155	
FAYETTEVILLE	NC	FAY		N	0.17	0.76	153	170	186	
RALEIGH	NC	RDU	RALEIGH/DURHAM	Y	0.13	0.61	234	270	298	
WILMINGTON	NC	ILM		Y	0.24	0.90	87	99	108	

DATA BASE FOR FDEP MESSAGE TRAFFIC MODEL

CENTER : ALBUQUERQUE (ZAB)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
ABQ	ALBUQUERQUE	NM	80	80	7	91	8	100	9
ROW	ROSWELL	NM	83	13	4	14	5	16	5
AMA	AMARILLO	TX	81	51	20	57	22	61	24
ELP	EL PASO	TX	80	57	5	63	6	71	6
PHX	PHOENIX	AZ	80	119	11	129	12	130	12
P90	PHOENIX	AZ	80	205	19	224	20	237	22
TUS	TUCSON	AZ	81	37	15	35	14	36	15
DMA	TUCSON	AZ	80	76	7	81	7	86	8
TOTALS FOR CENTER :	8 SITES			638	88	694	94	737	101

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : ATLANTA (ZTL)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
BHM	BIRMINGHAM	AL	80	120	11	136	12	149	14
MGM	MONTGOMERY	AL	81	69	23	78	26	86	29
MXF	MONTGOMERY	AL	81	74	7	80	7	89	8
FTY	ATLANTA	GA	80	28	12	32	13	35	14
PDK	ATLANTA	GA	80	30	12	35	14	37	15
ATL	ATLANTA	GA	80	456	41	497	45	537	49
CSG	COLUMBUS	GA	80	78	20	89	23	99	26
MCN	MACON	GA	81	85	21	97	24	112	28
WRB	WARNER ROBINS	GA	81	74	7	80	7	89	8
AVL	ASHVILLE	NC	80	41	11	48	13	53	14
CLT	CHARLOTTE	NC	80	141	13	163	15	181	16
GSO	GREENSBORO	NC	80	113	10	128	12	141	13
INT	WINSTON-SALEM	NC	81	21	9	24	10	26	11
GSP	GREER	SC	81	58	5	64	6	71	6
TRI	BRISTOL	TN	81	49	4	57	5	63	6
CHA	CHATTANOOGA	TN	80	64	6	74	7	81	7
TYS	KNOXVILLE	TN	81	79	7	91	8	101	9
TOTALS FOR CENTER :	17 SITES			1580	219	1773	247	1950	273

CENTER : BOSTON (ZBW)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
BED	BEDFORD	MA	80	17	7	20	8	21	9
BOS	BOSTON	MA	80	268	24	306	28	340	31
FMH	FALMOUTH	MA	80	46	4	49	4	52	5
ORH	WORCESTER	MA	83	11	4	13	5	14	5
BGR	BANGOR	ME	81	24	2	27	2	29	3
PWM	PORTLAND	ME	81	43	4	48	4	54	5
BDL	WINDSOR LOCKS	CT	80	116	11	132	12	153	14
MHT	MANCHESTER	NH	81	22	2	25	2	27	2
ALB	ALBANY	NY	80	90	8	104	9	117	11
RME	ROME	NY	81	58	5	63	6	71	6
SYR	SYRACUSE	NY	80	78	7	89	8	99	9
UCA	UTICA	NY	81	44	18	47	19	49	20
PVD	PROVIDENCE	RI	80	26	11	29	12	31	13
NCO	NORTH KINGSTOWN	RI	81	72	7	78	7	87	8
BTV	BURLINGTON	VT	80	56	5	63	6	69	6
TOTALS FOR CENTER : 15 SITES				971	119	1093	132	1213	147

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : CHICAGO (ZAU)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
CID	CEDAR RAPIDS	IA	80	82	28	90	30	98	33
ALO	WATERLOO	IA	83	25	2	29	3	33	3
CMI	CHAMPAIGN	IL	80	48	4	53	5	61	6
MDW	CHICAGO	IL	81	44	18	51	21	58	24
ORD	CHICAGO	IL	80	601	55	662	60	716	65
PWK	CHICAGO	IL	81	24	10	27	11	30	12
MLI	MOLINE	IL	81	53	19	60	21	67	24
PIA	PEORIA	IL	81	46	16	53	18	58	20
RFD	ROCKFORD	IL	81	84	8	91	8	97	9
FWA	FORT WAYNE	IN	80	67	6	78	7	87	8
SBN	SOUTH BEND	IN	81	88	8	100	9	112	10
GRR	GRAND RAPIDS	MI	81	55	20	64	23	70	25
AZO	KALAMAZOO	MI	80	46	4	51	5	57	5
MKG	MUSKEGON	MI	81	23	2	26	2	28	3
GRB	GREEN BAY	WI	81	65	25	73	28	79	31
MSN	MADISON	WI	81	54	19	62	22	68	25
MKE	MILWAUKEE	WI	80	134	12	152	14	166	15
TOTALS FOR CENTER :	17 SITES			1539	256	1722	287	1885	318

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : CLEVELAND (ZOB)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
DET	DETROIT	MI	80	39	16	46	19	50	21
DTW	DETROIT	MI	80	326	30	361	33	395	36
YIP	DETROIT	MI	81	47	19	56	23	62	25
FNT	FLINT	MI	80	49	15	57	18	64	20
JXN	JACKSON	MI	83	27	7	31	8	35	9
LAN	LANSING	MI	81	52	16	61	19	68	21
PTK	PONTIAC	MI	81	27	11	32	13	34	14
MBS	SAGINAW	MI	81	39	12	44	14	48	15
BUF	BUFFALO	NY	80	118	11	134	12	148	13
IAG	NIAGARA FALLS	NY	83	12	5	13	5	14	6
ROC	ROCHESTER	NY	81	104	9	111	10	114	10
CAK	AKRON	OH	80	77	7	88	8	99	9
BKL	CLEVELAND	OH	80	18	7	21	9	23	9
CGF	CLEVELAND	OH	83	21	9	25	10	27	11
CLE	CLEVELAND	OH	80	229	21	257	23	286	26
MFD	MANSFIELD	OH	83	34	3	39	4	45	4
TOL	TOLEDO	OH	81	92	8	107	10	122	11
YNG	YOUNGSTOWN	OH	81	47	16	51	17	55	19
ERI	ERIE	PA	81	43	15	50	17	58	19
AGC	PITTSBURGH	PA	81	30	12	35	14	38	16
PIT	PITTSBURGH	PA	80	312	28	354	32	393	36
CKB	CLARKSBURG	WV	83	32	3	36	3	40	4
TOTALS FOR CENTER :	22 SITES			1775	280	2009	321	2218	354

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : DENVER (ZDV)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
COS	COLORADO SPRINGS	CO	80	51	5	57	5	62	6
DEN	DENVER	CO	80	299	27	338	31	372	34
ARA	DENVER	CO	83	10	4	12	5	12	5
GJT	GRAND JUNCTION	CO	83	9	4	10	4	11	4
PUB	PUEBLO	CO	80	25	2	27	2	30	3
FMN	FARMINGTON	NM	83	13	5	14	6	15	6
CPR	CASPER	WY	83	16	1	17	2	19	2
CYS	CHEYENNE	WY	83	19	7	22	8	24	9
TOTALS FOR CENTER :	8 SITES			442	55	497	63	545	69

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : FORT WORTH (ZFW)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
TXK	TEXARKANA	AR	83	14	6	17	7	19	8
MLU	MONROE	LA	81	51	5	58	5	63	6
SHV	SHREVEPORT	LA	80	86	32	97	36	106	40
BAD	SHREVEPORT	LA	80	74	7	80	7	89	8
CSM	CLINTON	OK	83	11	4	12	5	13	5
OKC	OKLAHOMA CITY	OK	80	135	53	152	60	167	65
PWA	OKLAHOMA CITY	OK	83	19	8	22	9	24	10
TIK	OKLAHOMA CITY	OK	80	74	7	80	7	89	8
TUL	TULSA	OK	80	98	9	112	10	124	11
ABI	ABILENE	TX	80	44	17	46	18	49	19
DYS	ABILENE	TX	80	76	25	82	27	91	30
DAL	DALLAS	TX	80	93	38	104	43	116	48
DFW	DALLAS	TX	80	427	39	470	43	512	47
LBB	LUBBOCK	TX	80	117	11	124	11	129	12
MAF	MIDLAND	TX	80	79	30	91	34	99	37
SJT	SAN ANGELO	TX	81	16	6	17	7	18	7
TYR	TYLER	TX	83	10	4	12	4	13	5
ACT	WACO	TX	83	20	2	23	2	26	2
TOTALS FOR CENTER :	18 SITES			1444	303	1599	335	1747	368

CENTER : HOUSTON (ZHU)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
MOB	MOBILE	AL	81	60	5	69	6	76	7
BTR	BATON ROUGE	LA	81	54	16	61	18	72	22
LCH	LAKE CHARLES	LA	83	34	3	40	4	45	4
MSY	NEW ORLEANS	LA	80	171	16	193	18	215	20
NEW	NEW ORLEANS	LA	83	23	10	27	11	29	12
LFT	LAFAYETTE	LA	81	96	9	115	10	130	12
GPT	GULFPORT	MS	81	39	4	45	4	49	4
AUS	AUSTIN	TX	80	112	42	129	48	140	53
BSM	AUSTIN	TX	81	74	7	80	7	89	8
BPT	BEAUMONT	TX	81	63	6	73	7	81	7
BRO	BROWNSVILLE	TX	83	23	9	25	10	27	11
CLL	COLLEGE STATION	TX	83	17	7	19	8	21	9
CRP	CORPUS CHRISTI	TX	80	82	7	93	8	101	9
IAH	HOUSTON	TX	80	348	32	388	35	426	39
HOU	HOUSTON	TX	81	102	42	113	47	126	52
MFE	MC ALLEN	TX	83	10	4	11	4	11	5
SAT	SAN ANTONIO	TX	80	182	17	199	18	212	19
TOTALS FOR CENTER :	17 SITES			1490	236	1680	263	1850	293

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : JACKSONVILLE (ZJX)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
DHN	DOTHAN	AL	83	21	9	23	9	24	10
DAB	DATONA BEACH	FL	80	59	5	66	6	74	7
GNV	GAINSVILLE	FL	83	16	7	18	8	20	8
JAX	JACKSONVILLE	FL	81	188	17	209	19	228	21
PFN	PANAMA CITY	FL	83	18	8	21	9	23	10
PNS	PENSACOLA	FL	81	70	6	75	7	79	7
TLH	TALAHASSEE	FL	81	46	4	54	5	60	5
ABY	ALBANY	GA	83	18	6	21	7	22	8
AGS	AUGUSTA	GA	80	47	16	55	19	62	22
SAV	SAVANNAH	GA	81	60	5	68	6	75	7
CHS	CHARLESTON	SC	80	71	6	80	7	86	8
CAE	COLUMBIA	SC	80	57	5	66	6	73	7
FLO	FLORENCE	SC	83	9	1	10	1	11	1
TOTALS FOR CENTER :	13 SITES			680	95	766	109	837	121

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : KANSAS CITY (ZKC)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
ALN	ALTON	IL	83	13	5	15	6	16	7
DEC	DECATUR	IL	83	19	8	22	9	23	9
MWA	MARION	IL	83	15	5	17	6	19	7
SPI	SPRINGFIELD	IL	81	52	5	60	5	66	6
HUT	HUTCHINSON	KS	83	16	6	19	7	21	8
SLN	SALINA	KS	83	16	6	18	7	19	8
ICT	WICHITA	KS	80	82	7	93	8	100	9
COU	COLUMBIA	MO	83	19	7	22	8	24	9
JLN	JOPLIN	MO	83	15	6	17	6	19	7
MCI	KANSAS CITY	MO	80	183	17	206	19	228	21
MKC	KANSAS CITY	MO	80	50	21	57	23	62	25
STJ	ST. JOSEPH	MO	83	10	4	11	4	12	4
STL	ST. LOUIS	MO	80	260	24	292	27	321	29
SUS	ST. LOUIS	MO	83	17	7	20	8	21	9
SGF	SPRINGFIELD	MO	83	33	3	37	3	42	4
TOTALS FOR CENTER :	15 SITES			800	131	906	146	993	162

CENTER : INDIANAPOLIS (ZID)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
EVV	EVANSVILLE	IN	80	56	5	63	6	72	7
IND	INDIANAPOLIS	IN	80	197	18	227	21	255	23
LAF	LAFAYETTE	IN	83	19	7	23	9	26	10
MIE	MUNCIE	IN	83	23	8	27	10	30	11
HUF	TERRA HAUTE	IN	83	26	2	31	3	35	3
CVG	COVINGTON	KY	80	139	13	157	14	175	16
LEX	LEXINGTON	KY	81	50	16	58	18	63	20
SDF	LOUISVILLE	KY	81	123	11	141	13	159	14
LUK	CINCINNATI	OH	81	2	1	2	1	2	1
CMH	COLUMBUS	OH	80	177	16	202	18	225	20
OSU	COLUMBUS	OH	83	15	6	17	7	19	8
DAY	DAYTON	OH	80	95	9	107	10	118	11
CRW	CHARLESTON	WV	81	61	21	70	24	77	26
HTS	HUNTINGTON	WV	83	30	11	34	12	36	13
TOTALS FOR CENTER :	14 SITES			1013	144	1159	166	1292	183

CENTER : LOS ANGELES (ZLA)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
BFL	BAKERSFIELD	CA	81	27	2	31	3	34	3
BUR	BURBANK	CA	80	149	14	172	16	192	17
CRQ	CARLSBAD	CA	83	20	8	23	10	25	10
FUL	FULLERTON	CA	83	18	7	21	9	23	10
LGB	LONG BEACH	CA	81	60	24	67	27	74	31
LAX	LOS ANGELES	CA	80	365	33	397	36	425	39
EDW	MUROC	CA	80	99	9	102	9	107	10
ONT	ONTARIO	CA	80	56	5	64	6	69	6
040	ONTARIO	CA	80	196	18	223	20	253	23
OXR	OXNARD	CA	83	21	9	26	11	29	12
SAN	SAN DIEGO	CA	81	99	41	108	45	114	47
NKX	SAN DIEGO	CA	80	204	19	218	20	236	21
NZJ	SANTA ANA	CA	80	74	7	80	7	89	8
SNA	SANTA ANA	CA	80	84	35	94	39	105	43
SBA	SANTA BARBARA	CA	81	24	2	28	3	31	3
SMO	SANTA MONICA	CA	83	17	7	20	8	22	9
VNY	VAN NUYS	CA	81	24	10	28	12	30	12
LAS	LAS VEGAS	NV	80	152	14	171	16	187	17
TOTALS FOR CENTER : 18 SITES				1689	264	1873	297	2045	321

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : MEMPHIS (ZME)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
HSV	HUNTSVILLE	AL	81	66	6	75	7	85	8
FYV	FAYETTEVILLE	AR	83	27	11	31	12	34	14
FSM	FORT SMITH	AR	81	45	17	53	20	60	22
HOT	HOT SPRINGS	AR	83	12	5	14	5	16	6
LIT	LITTLE ROCK	AR	80	97	9	110	10	120	11
PBF	PINE BLUFF	AR	83	6	2	7	2	7	3
PAH	PADUCAH	KY	83	17	5	19	6	21	7
CGI	CAPE GIRARDEAU	MO	83	12	4	14	5	15	5
GLH	GREENVILLE	MS	83	12	4	14	5	15	5
JAN	JACKSON	MS	81	56	5	65	6	73	7
NMM	MERIDIAN	MS	81	50	5	53	5	55	5
MEM	MEMPHIS	TN	81	189	17	214	19	233	21
BNA	NASHVILLE	TN	81	120	11	136	12	149	14
TOTALS FOR CENTER :	13 SITES			709	101	805	114	883	128

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : MIAMI (ZMA)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
FLL	FT. LAUDERDALE	FL	80	106	44	122	50	135	55
FMY	FT. MYERS	FL	81	27	2	30	3	32	3
MLB	MELBOURNE	FL	83	27	11	30	12	33	14
MIA	MIAMI	FL	81	371	34	408	37	443	40
TNT	MIAMI	FL	83	5	2	6	2	6	2
ORL	ORLANDO	FL	81	25	10	29	12	31	13
MCO	ORLANDO	FL	81	122	11	139	13	158	14
PIE	ST. PETERSBURG	FL	83	14	6	15	6	17	7
SRQ	SARASOTA	FL	81	24	10	26	11	29	12
TPA	TAMPA	FL	81	199	18	224	20	248	23
PBI	WEST PALM BEACH	FL	81	85	8	99	9	110	10
TOTALS FOR CENTER : 11 SITES				1005	156	1128	175	1242	193

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : MINNEAPOLIS (ZMP)

LOCID	CITY	ST	STATUS	NEAR-RANGE		MID-RANGE		LONG-RANGE	
				IN-TRF	OUT-TRF	IN-TRF	OUT-TRF	IN-TRF	OUT-TRF
DSM	DES MOINES	IA	80	76	7	86	8	98	9
SUX	SIOUX CITY	IA	80	27	10	30	11	33	13
DLH	DULUTH	MN	80	30	3	32	3	35	3
MSP	MINNEAPOLIS	MN	80	195	18	221	20	243	22
RST	ROCHESTER	MN	81	27	2	30	3	33	3
GRI	GRAND ISLAND	NE	83	16	6	18	7	19	8
LNK	LINCOLN	NE	80	94	36	104	39	110	42
OMA	OMAHA	NE	80	59	24	65	27	73	30
OFF	OMAHA	NE	80	71	6	77	7	85	8
BIS	BISMARK	ND	83	13	1	14	1	15	1
FAR	FARGO	ND	83	53	20	57	22	60	23
GFK	GRAND FORKS	ND	83	14	6	16	7	17	7
FSD	SIOUX FALLS	SD	81	62	24	67	26	71	27
LSE	LA CROSSE	WI	83	22	8	26	9	29	10
TOTALS FOR CENTER :	14 SITES			759	171	843	190	921	206

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : NEW YORK (ZNY)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
ILG	WILMINGTON	DE	81	24	10	27	11	29	12
ACY	ATLANTIC CITY	NJ	81	49	4	54	5	59	5
EWR	NEWARK	NJ	80	132	54	149	61	164	67
TEB	TETERBORO	NJ	81	46	19	54	22	60	24
TTN	TRENTON	NJ	83	16	7	19	8	21	9
BGM	BINGHAMTON	NY	81	38	13	44	15	53	18
ELM	ELMIRA	NY	81	33	12	37	13	41	15
ISP	ISLIP	NY	81	180	65	191	69	195	70
N90	NEW YORK	NY	80	342	31	383	35	412	37
N90	NEW YORK	NY	80	342	31	383	35	412	37
JFK	NEW YORK	NY	80	217	20	238	22	259	24
LGA	NEW YORK	NY	80	237	96	261	106	292	119
HPN	WHITE PLAINS	NY	81	92	36	104	40	118	46
ABE	ALLENTOWN	PA	80	45	4	49	4	52	5
CXY	HARRISBURG	PA	81	84	31	92	34	102	37
MDT	MIDDLETOWN	PA	80	26	11	30	12	33	13
PHL	PHILADELPHIA	PA	80	271	25	309	28	342	31
PNE	PHILADELPHIA	PA	83	16	7	19	8	21	9
RDG	READING	PA	83	18	2	21	2	23	2
AVP	SCRANTON	PA	81	50	5	56	5	59	5
IPT	WILLIAMSPORT	PA	83	20	7	23	8	25	9
TOTALS FOR CENTER :	21 SITES			2278	490	2543	543	2772	594

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : OAKLAND (ZOA)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
FAT	FRESNO	CA	81	68	27	76	30	84	33
MRY	MONTEREY	CA	81	80	32	87	35	91	37
OAK	OAKLAND	CA	80	297	27	334	30	367	33
O90	OAKLAND	CA	80	423	38	458	42	495	45
MCC	SACRAMENTO	CA	80	203	18	222	20	243	22
SMF	SACRAMENTO	CA	81	65	27	73	30	82	34
SAC	SACRAMENTO	CA	81	29	12	34	14	37	15
SFO	SAN FRANCISCO	CA	80	226	93	249	103	269	111
SJC	SAN JOSE	CA	80	76	31	83	34	92	38
SCK	STOCKTON	CA	83	25	2	28	3	31	3
RNO	RENO	NV	81	41	4	45	4	49	4
TOTALS FOR CENTER : 11 SITES				1533	311	1689	345	1840	375

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : SALT LAKE CITY (ZLC)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
BOI	BOISE	ID	80	72	29	79	32	84	34
BIL	BILLINGS	MT	80	77	32	84	35	89	37
GFA	GREAT FALLS	MT	80	71	29	77	32	86	36
HLN	HELENA	MT	83	6	2	7	3	7	3
MSO	MISSOULA	MT	83	7	3	7	3	8	3
SLC	SALT LAKE CITY	UT	80	99	9	112	10	121	11
TOTALS FOR CENTER :	6 SITES			332	104	366	115	395	124

CENTER : SEATTLE (ZSE)

LOCID	CITY	ST	STATUS	NEAR-RANGE IN-TRF	NEAR-RANGE OUT-TRF	MID-RANGE IN-TRF	MID-RANGE OUT-TRF	LONG-RANGE IN-TRF	LONG-RANGE OUT-TRF
EUG	EUGENE	OR	81	32	3	37	3	40	4
MFR	MEDFORD	OR	81	15	6	18	7	20	8
PDT	PENDLETON	OR	83	6	2	7	3	8	3
PDX	PORTLAND	OR	81	145	13	165	15	182	17
PAE	EVERETT	WA	83	14	6	16	7	17	7
MWH	MOSES LAKE	WA	83	20	8	23	9	25	10
PSC	PASCO	WA	81	31	12	35	14	38	15
BFI	SEATTLE	WA	80	34	14	40	16	43	18
SEA	SEATTLE	WA	81	186	17	210	19	234	21
SKA	SPOKANE	WA	80	69	6	75	7	81	7
GEG	SPOKANE	WA	80	52	21	58	24	62	25
TCM	TACOMA	WA	80	65	22	71	24	79	27
YKM	YAKIMA	WA	83	21	9	24	10	27	11
TOTALS FOR CENTER :	13 SITES			690	139	779	158	856	173

FDEP MESSAGE TRAFFIC PROJECTIONS

CENTER : WASHINGTON (ZDC)

LOCID	CITY	ST	STATUS	NEAR-RANGE		MID-RANGE		LONG-RANGE	
				IN-TRF	OUT-TRF	IN-TRF	OUT-TRF	IN-TRF	OUT-TRF
DCA	WASHINGTON	DC	80	238	22	258	23	274	25
BWI	BALTIMORE	MD	80	180	16	207	19	239	22
ADW	CAMP SPRINGS	MD	80	38	15	38	16	39	16
IAD	CHANTILLY	VA	80	145	13	170	15	194	18
LYH	LYNCHBURG	VA	83	16	6	18	7	20	8
PHF	NEWPORT NEWS	VA	81	15	6	17	7	18	8
ORF	NORFOLK	VA	80	150	14	164	15	175	16
RIC	RICHMOND	VA	80	79	7	90	8	99	9
ROA	ROANOKE	VA	81	53	5	60	5	65	6
FAY	FAYETTEVILLE	NC	80	73	25	81	28	88	30
RDU	RALEIGH	NC	81	86	8	99	9	110	10
ILM	WILMINGTON	NC	81	49	4	56	5	61	6
TOTALS FOR CENTER :	12 SITES			1122	141	1258	157	1382	174

FDEP MESSAGE TRAFFIC PROJECTIONS

APPENDIX B

INTERFACE CONTROL PROCEDURES

B.1 INTRODUCTION

This appendix presents suggested interface control requirements for FDEP system communications links between:

(1) RCUs and ARTCC concentrators, and

(2) NAS 9020 computers and ARTCC concentrators.

These are presented in a manner to facilitate their adaptation into the FDIO specifications. As a result, the ARTCC concentrators are specifically considered to be CCUs. Details presented for the RCU/Concentrator interface are also applicable should the NADIN concentrators be used for the CCU function.

B.2 RCU/CONCENTRATOR INTERFACE

B.2.1 INTRODUCTION

B.2.1.1 Purpose

The information contained herein describes the interface control requirements for Flight Data Entry and Printout (FDEP) communications links between the Central Control Unit (CCU) and the Remote Control Units (RCUs) specified in the Flight Data Input/Output (FDIO) program. These procedures have been developed so as to also be applicable (with minor modifications) should NADIN concentrators functionally replace the CCUs.

B.2.1.2 Scope

This section addresses interface control requirements at three levels:

- physical, i.e., the communications lines, modems, and the electrical/mechanical connections;
- link control, i.e., the control of transmission; and
- message, i.e., the content of actual data transmitted.

B.2.1.3 System Overview

The FDEP communications considered here are of two basic types: (1) output messages, i.e., transmissions from the NAS 9020 computer to terminals (printers) located at remote FDEP sites, and (2) input, i.e., transmissions from remote terminals (keyboards) at remote FDEP sites to the NAS 9020. Under the FDIO replacement program all such communications will be routed through CCUs collocated with the NAS 9020 at the Air Route Traffic Control Center (ARTCC), and RCUs located at the remote sites.

The CCU's functions involve both transmissions to and from the NAS 9020 and to and from the RCUs. This section is concerned only with the latter. Pertinent CCU functions related to messages on the CCU to RCU links include:

- implementing the data link control procedures (protocol) for the output messages,
- transmitting output messages to the appropriate RCUs,
- determining the acceptability of input messages from RCUs, implementing exception recovery procedures (if pertinent), and
- buffering acceptable input messages for subsequent transmission to the NAS 9020 computer.

Pertinent RCU functions related to messages on the CCU to RCU links include:

- determining the acceptability of output messages from the CCU, implementing exception recovery procedures (if pertinent),
- buffering acceptable output messages for subsequent transmission to the appropriate terminals,
- implementing the data link control procedures (protocol) for the input messages, and
- transmitting input messages to the CCU.

Both the CCUs and RCUs have other functions related to FDEP message transmissions; e.g., the CCU must convert message text between EBCDIC and ASCII codes, and the RCUs must provide editing logic for the remote terminals. Such functions are considered pertinent to NAS 9020/CCU and the RCU/terminal interfaces, respectively, and are not considered in this section.

B.2.2 PHYSICAL CONTROL LEVEL

B.2.2.1 Communications Lines

Two types of physical links will be provided between CCUs and RCUs — primary service links, which will be used whenever possible, and back-up links, which will be used when primary links are down.

(1) Primary Links — The primary communications lines shall be 4-wire, voice grade, non-switched leased lines. These may be either multipoint or point-to-point configurations. Each CCU shall have 25 ports to accommodate such circuits; however, not all 25 ports can be used for primary circuits, as will be discussed below. (The NADIN concentrators will accommodate many more ports.)

(2) Back-up Links — Each RCU shall be provided with a dial back-up capability for use in the event of leased line outage. This capability may be automatic or manual. This back-up service shall use 2-wire, voice grade, switched lines. Some of the 25 ports in each CCU must be reserved to accommodate the dial-up lines.

B.2.2.2 Modems

The transmission lines must be interfaced with the RCUs and CCUs by modems.

(1) Primary Links — Modems capable of handling full duplex, synchronous transmissions at 2400 bps shall be used for the primary leased line. Thus there shall be one such modem at each RCU and one for each primary circuit (multipoint or point-to-point) at each CCU. Spare modems shall be available in the event of modem failure.

(2) Back-up Links — Modems capable of handling half duplex, synchronous transmissions at 2400 bps shall be used for the back-up service. Thus there shall be one such modem at each RCU and one for each back-up port at each CCU. Spare modems shall be available in the event of modem failure. (If the primary

service modem can be used for the back-up service, duplication is not required.) As suggested earlier, the back-up system may be automatic or manual. If the fully automatic option is selected, automatic dial capability is required for the RCU back-up-line modems and automatic answer capability for the CCU back-up-line modems. Partially automated options are also feasible, involving either the automatic dial or the automatic answer capability.

B.2.2.3 Electrical/Mechanical Interface

The electrical/mechanical interface between the modem and the control units (RCUs and CCUs) shall be in accordance with EIA standard RS-449 [9].

B.2.3 LINK CONTROL LEVEL

B.2.3.1 Procedures

The link level protocol to be used between the RCUs and CCU shall be the bit-oriented ANSI X3.66, Advanced Data Communication Control Procedure (ADCCP) [5]. ADCCP provides for three classes of procedures. Only two of these shall be used for FDEP systems:

- Unbalanced Normal (UN) — Such procedures involve one station designated as the primary station and any number of secondary stations. The primary station controls the link through the transmission of commands. The secondaries transmit responses to commands. Both types of stations can transmit information (e.g., FDEP messages); however, secondary stations can do so only in response to a specific command (poll). This class of procedures shall be used for FDIO multipoint links between RCUs and CCU and for the dial back-up links, with the CCU always designated as the primary station.

- Balanced Asynchronous (BA) — Under such procedures, each of the two stations on a point-to-point link is a combined (primary and secondary) station. As appropriate, either of the two stations can take on the primary role (send commands), causing the other to take on the secondary role (send responses). This class of procedures shall be used for the primary point-to-point links

between RCUs and CCUs in each FDEP system. With a dedicated full duplex link, such as specified for primary FDEP circuits, no contention problems will exist.

The following subsections provide a general description of ADCCP focused on the two classes of procedures indicated above for FDEP application. Emphasis is placed on the procedure variations and options that must be implemented for FDEP. Greater detail can be found in the referenced ADCCP standards publication, ANSI X3.66-1979.

Because of the many similarities in the two classes of procedures, it will be convenient to use the terms primary and secondary, when applied to stations, to also include combined stations in the indicated roles. Thus "primary stations" should be understood to mean "primary stations under UN procedures and combined stations in the primary role under BA procedures."

B.2.3.2 Frame Structure

The unit of transmission under ADCCP is the frame. A frame may, but need not, include a message block (information field); frames with no information field are used for link control only. Each frame transmitted from any type of station must contain the following, in the order indicated:

- an opening flag sequence;
- an address field;
- a control field;
- an information field (optional);
- a frame check sequence; and
- an ending flag sequence.

Flag	Address Field	Control Field	Information Field (Optional)	FCS	Flag

B.2.3.3 Flag Sequence

The flag sequences serve to synchronize a frame. The flag sequence shall be the bit octet — 01111110. The sequence -- 011111101111110 -- shall be recognized as two flag sequences. A single flag sequence can be used as the ending flag for one frame and the opening flag for the next frame.

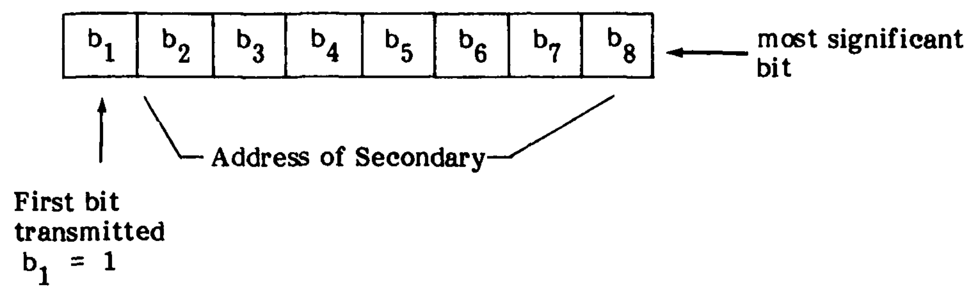
Each receiving station shall constantly monitor the stream of bits received to identify the flag sequences. In order to avoid misinterpretation of other control data or information field contents as flag sequences, the transmitting station shall implement a "zero-bit insertion" process. This process requires that, prior to a transmission, a zero bit be inserted immediately following any sequence of five contiguous one bits other than those in the flags. This includes all such sequences found in the string of bits constituting the address field, the control field, the information field (if present) and the frame check sequence.

In monitoring the input bit stream, the receiving station shall isolate all sequences of 5 one bits. When such a sequence is found, the next bit shall be checked. If that bit is a zero, the 5 one bits shall be passed and the zero deleted. If the bit following the 5 one bits is another one bit, the receiving station shall check the next bit. If it is a zero, a flag is identified; otherwise an abort signal (7 to 14 contiguous one bits) is identified and the current frame is discarded.

B.2.3.4 Address Field

ADCCP requires that a unique address be associated with all secondary stations on a link (this includes all combined stations). Any transmission to or from a secondary station shall contain the address of that station in the address field. A transmission from a primary station to more than one secondary stations on a multipoint line shall include a group or global address, which appropriate secondary stations shall be capable of recognizing.

ADCCP provides for a multi-octet address field. For FDEP applications, only a single octet shall be used. Nevertheless, in order to be consistent with the multi-octet option, the least significant bit of each address shall be 1. Address fields shall be transmitted with the least significant bit first, as indicated below:



Since only the address of the secondary station is used, the address field indicates the respective roles of the combined stations under BA procedures. Thus if on a primary point-to-point link the CCU is assigned the address 0 and the RCU the address 1, the roles are identified as follows:

Direction of Transmission	Address Field b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	Primary Role	Secondary Role	Meaning of Control Sequence
CCU→RCU	1	1	0	0	0	0	0	0	CCU	RCU	Command
CCU←RCU	1	1	0	0	0	0	0	0	CCU	RCU	Response
CCU→RCU	1	0	0	0	0	0	0	0	RCU	CCU	Response
CCU←RCU	1	0	0	0	0	0	0	0	RCU	CCU	Command

The global address -- 11111111 -- shall be used for transmissions being directed simultaneously to all RCUs on a multipoint line. For FDEP applications, group addresses (other than the global address) shall be used only to permit simultaneous transmission of messages to a tower and its associated radar approach control facility (e.g., TRACON), when they have distinct RCUs. It shall be a function of RCU firmware to determine to which specific printer at a site a message will be directed. The null address -- 00000000 -- shall be used in situations where it is desired to exercise a station's transmit abilities without requiring station action or reply.

B.2.3.5 Control Field

The control field is used to indicate the nature of the transmission, to communicate commands and responses between primary and secondary stations and to acknowledge receipt of acceptable information frames. ADCCP permits use of a one-or two-octet control field. Only a single octet shall be used for FDEP applications. This limits the number of unacknowledged information frames, from one station to another, to seven.

In order to describe the structure of the control field, it is useful first to define a few related parameters and concepts.

B.2.3.5.1 Control Parameters and Concepts

- Frame Sequence Number — Each station shall assign a sequence number to each information frame transmitted. A separate sequence of numbers shall be used for each station with which that station communicates. Such sequence numbers must fall in the range of 0 to 7 (000 to 111, in binary notation). Thus, after information frame 7 has been transmitted to a particular station, the next information frame transmitted to that station shall be asisgned the sequence number 0 (i.e., the frame numbers are incremented by 1, modulo 8).

- Send Variable — Each station shall maintain a set of send variables, S(B). Each of these variables shall be initialized to 0 and then incremented by 1, modulo 8, whenever the transmission of an information frame to the particular station (B) is completed. (S(B) shall not be incremented when a frame is aborted.)

- Receive Variable — Each station shall similarly maintain a set of receive variables, R(A), which shall be initialized to 0. Each of these variables shall be incremented by 1, modulo 8, whenever an information frame with sequence number equal to R(A) is received from the particular station (A). (Note that since all FDEP stations both send and receive messages, each shall maintain both send and receive variables.)

- Poll/Final (P/F) Bit — One bit position within each control frame shall be used to transmit a poll or final (P/F) bit. The term poll bit is used in connection with

transmissions from primary stations (i.e., commands). When the poll bit is transmitted (i.e., the P/F bit position in a primary station's transmission contains a 1) the secondary is "commanded" to respond. The term final bit is used in connection with transmissions from secondary stations (i.e., responses). When the final bit is transmitted, the secondary station is indicating that it has responded to a poll command. If the response is one or more information frames, the final bit shall be set only in the last frame transmitted in response to the poll.

B.2.3.5.2 Control Field Structure

ADCCP groups the various types of frames into three categories — information (transfer), supervisory and unnumbered. Each of these categories requires a distinct format for the control field. Information frames are the ones generally used to transmit information (e.g. FDEP messages). The other frames may also contain information fields, but such information is generally for link control purposes. Information frames, on the other hand, can also be used to perform some link control fucntions. Supervisory and unnumbered frames are used to carry out link control functions.

The formats indicated below shall be used for the control field:

Frame Type	Format							
Bit Position:	1	2	3	4	5	6	7	8
Information	0		N(S)		P/F		N(R)	
Supervisory	1	0	C	C	P/F		N(R)	
Unnumbered	1	1	M	M	P/F	M	M	M

Notes:

1. The first or first and second bits indicate the format being used.

2. The fifth bit position shall always be used for the P/F bit.

3. N(S) shall be the value of the transmitting station's send variable, S(B), at the start of transmission.

4. N(R) shall be the value of the transmitting station's receive variable, R(B) at the start of transmission.

5. N(S) and N(R) shall be transmitted with the least significant bit first.

6. The third and fourth bits of the control field in supervisory frames (designated C) shall be used to identify the specific supervisory function. These are discussed later.

7. Bit positions 3, 4, 6, 7, and 8 in unnumbered frames (designated M) shall be used to identify the specific unnumbered function. These also are defined later.

B.2.3.6 Information Field

When included, the information field is transparent to ADCCP, i.e., the link control procedures will accept any sequence of bits as an information field. There shall, however, be a limit on the size of the field. For FDEP application, this limit shall be 2000 bits (or 250 8-bit characters), excluding the zero insertion bits discussed earlier. In order to transmit longer messages, the messages shall be broken into two or more blocks of 2000 (or fewer) bits and each block shall be transmitted in a separate frame.

Information frames will almost always include an information field. Supervisory frames shall never include an information field. Generally, unnumbered frames must not include such fields. There are two exceptions, however. An unnumbered frame for the function XID (exchange identification, discussed later) may optionally include an information field providing supervisory data. Similarly, if a non-reserved function (also discussed later) is used, an information field may be included in the frame.

B.2.3.7 Frame Check Sequence

The frame check sequence (FCS) shall be a 16-bit (2 octet) number generated at the transmitting station by applying a special algorithm to the string of bits that make up the address field, the control field and (if present) the information field, prior to zero insertion. The value of the FCS shall be determined and transmitted as part of each frame.

The receiving station, after removing the flag sequences and the inserted zeros, shall determine if the received FCS is consistent with the remainder of the transmission. Inconsistency implies an error in transmission and shall cause the transmission to be unacceptable.

Appendix D to ANSI X3.66-1979 defines the FCS in detail and suggests techniques for implementing this process.

B.2.3.8 Control Functions

As indicated earlier, ADCCP provides for a variety of control functions. These are defined as a series of basic commands and responses together with a series of optional commands and responses. The referenced ANSI standard for ADCCP describes all of these functions in detail. The following outlines those that shall be implemented for FDEP applications.

B.2.3.8.1 Basic Functions

The basic control functions include both commands (i.e., from primary stations) and response (i.e., from secondary stations). The following identifies these functions as they apply to FDEP:

Function	Type*	Meaning
I	C&R	Information being transferred.
RR	C&R	Receive Ready
RNR	C&R	Receive Not Ready
FRMR	R	Frame Reject
SNRM	C	Set Normal Response Mode (UN procedures only)
SABM	C	Set Asynchronous Balanced Mode (BA procedures only)
DISC	C	Disconnect
UA	R	Unnumbered Acknowledgement
DM	R	Disconnected Mode

*C = Command; R = Response

In addition there is a basic command RSET (Reset) for BA procedures which will not be used for FDEP.

B.2.3.8.2 Optional Functions

ADCCP provides eleven options for adding or deleting control functions. The ones that shall be implemented for FDEP are:

Option#	Add/ Delete*	Type*	Function	Meaning
1	A	C&R	XID	Exchange Identification
	A	R	RD	Request Disconnect
2	A	C&R	REJ	Reject
7	A	C&R	—	Multiple Octet Address
11	D	C	RSET	(Delete the Basic Reset Command)

*A = Add function; D = Delete Function; C = Command; R = Response

In addition ADCCP provides up to four non-reserved functions that can be defined and implemented by the system designer. No such fucntions are envisioned as being needed for FDEP.

B.2.3.8.3 Function Codes

The various functions indicated above shall be designated through codes in the control field of a frame. The information transfer function, I, shall be designated directly by the use of an information transfer format (0 in bit position 1, see Section B.2.3.5.2). The remaining functions shall be designated as follows:

- Supervisory Frames

Function	Control Field Bit Positions	
	3	4
RR	0	0
RNR	1	0
REJ	0	1

- Unnumbered Frames

Function	Control Field Bit Positions				
	3	4	6	7	8
SNRM	0	0	0	0	1
SABM	1	1	1	0	0
DISC	0	0	0	1	0
XID	1	1	1	0	1
UA	0	0	1	1	0
DM	1	1	0	0	0
FRMR	1	0	0	0	1
RD	0	0	0	1	0

B.2.3.9 Exception Conditions

Six exception conditions can be anticipated in the FDEP applciations of ADCCP. These are described briefly below. The referenced ANSI standard for ADCCP should be used for greater detail.

B.2.3.9.1 Busy Condition

A station is considered "busy" when, due to internal constraints (e.g., buffer limitations), it temporarily cannot accept additional information frames. Such a condition shall be reported at the first opportunity to all other appropriate stations using an RNR frame.

Upon receipt of an RNR frame, a station shall not transmit new information frames to the busy station. An information frame in the process of being transmitted can be aborted or completed. Transmission of other types of frames to or from the busy station can continue during the busy condition.

The clearance of a busy condition shall be reported by:

- transmission of an RR, REJ, SNRM, SABM, or UA frame, with or without the P/F bit set to 1, or

- transmission of an information frame with the P/F bit set to 1.

B.2.3.9.2 FCS Error

Errors introduced during the transmission of a frame will almost always cause an FCS error, i.e., cause the received value of the FCS to differ from the expected value. Frames with such an error shall be discarded. No other specific action shall taken when such an error is detected (however, see B.2.3.9.4 below).

B.2.3.9.3 Frame Reject Condition

When a frame is received with no FCS error, but contains (1) an invalid control field, (2) an invalid N(R) or (3) an information field with more than 2000 bits, a frame reject

condition exists. A secondary station, upon detecting such a condition, shall notify the primary station with a FRMR response. A primary station upon detecting such an error or upon receiving an FRMR response shall transmit a mode setting command (SNRM, SABM, or DISC). Higher level recovery functions may also be implemented by the primary station.

B.2.3.9.4 Frame Sequence Error

Whenever a station receives an otherwise error-free information frame, it shall check to insure that the value of N(S) corresponds to the receive variable R(A). If the two are not identical, a frame sequence error has occurred. At the earliest opportunity the receiving station shall transmit an REJ frame to the original transmitting station, with N(R) set to R(A). The information field(s) from the erroneous frame and any subsequent information frames from that transmitting station shall be discarded, until one with N(S) equal to R(A) is received. Other control information (e.g., the P/F bit and N(R)) from those frames will be used. The original transmitting station, upon receiving the REJ frame shall retransmit the erroneous frame and any subsequent information frames (in order) at the earliest opportunity.

B.2.3.9.5 Unacknowledged Frames

Each time a station receives an information or supervisory frame, it expects acknowledgement (through the N(R) parameter) of information frames it transmitted. To facilitate retransmission of unacknowledged information frames, each station shall implement checkpoint recovery, as follows:

- A checkpoint cycle is defined (1) for a primary station, as the period between the transmission of a frame with the P bit set to 1 and the next receipt of a frame with the F bit set to 1 from the secondary to which the poll bit was directed, and (2) for a secondary station, as the period between the transmission of a frame with the F bit set to 1 and the next receipt of a frame with the P bit set to 1 from the primary. (A cycle does not end with an unnumbered frame, however.)

- At the end of each cycle, the station will retransmit any unacknowledged frames (per the value of N(R) received) that had been transmitted before the start of

the cycle, and any subsequent frames transmitted. This is referred to as checkpoint retransmission.

- If an REJ frame with the P/F bit set to 0 is received during such a cycle, actions pertinent to the REJ condition, rather than checkpoint retransmission, will be implemented.

B.2.3.9.6 Time-Out

Often an expected acknowledgement or response is not received due to transmission losses or FCS errors (for messages in either direction). To help detect such conditions efficiently, time-out functions shall be implemented. Time-out functions shall (1) initialize a timer when a transmission requiring an acknowledgement or response is sent, (2) stop the timer when the acknowledgement or response is received, and (3) note a time-out condition when a prespecified time has elapsed without the expected acknoweldgement or response having been received. If the time-out condition occurs, recovery actions shall be taken, generally involving retransmission of the frame that started the process.

For FDEP applications, at least two time-out functions shall be included. One for polls from primary stations and one for REJ frames (with the P/F bit set to 1) from either primary or secondary stations. These functions shall recognize a time out condition after 8 seconds have elapsed.

B.2.4 MESSAGE LEVEL

B.2.4.1 Code Set

The information fields of FDEP transmissions between RCUs and CCUs shall be constructed using the International Alphabet No. 5 (IA-5) seven level ASCII code (ANSI Standard X3.4-1968 [10]). This code has been specified as the one to be generated and/or accepted by remote FDIO replacement equipment. This code, however, is not used by the NAS 9020 computer; hence the CCU shall perform the necessary code conversion (see Section B.3).

B.2.4.2 Message Format

The message format shall be consistent with that specified for NADIN. Portions of the NADIN message format requrements, however, remain to be specified by the NADIN Program Office. The requirements presented here include, therefore, only the details currently available. Items designated "to be specified by NADIN" shall be handled as follows:

- At the time these elements are to be implemented for FDEP, it shall be determined if they have been specified for NADIN.
- If so, the NADIN requirements shall be implemented. If not, the FDIO contractor can handle these elements in an arbitrary manner, but with the understanding that modifications might be required at a later time (i.e., in a way that shall facilitate such subsequent modifications).
- If the latter approach is used, appropriate modifications shall be made at such time that FDEP may be integrated into NADIN.

B.2.4.2.1 Message Size and Components

The length of the information field shall not exceed 250 characters (2000 bits). This includes the three required components of the field:

- a heading, containing administrative information;
- the text, i.e, the message being transferred; and
- an ending, i.e., a flag denoting the end of the message (block).

Should the message be so long as to cause the combined length of the three components to exceed 250 characters, the message shall be broken down into two or more blocks. Each message block shall be imbedded in a separate transmission frame, with its own heading and ending.

B.2.4.2.2 Message Heading

The message heading shall consist of the following elements. The elements shall be organized in lines as indicated and no line shall exceed 69 characters in length.

(1) Start of Heading — The start of heading indicator shall consist of SOH (ASCII character 0/1) followed by GS (ASCII character 1/13).

(2) Supervisory Information — Supervisory information shall consist of a transmission identification to be specified by NADIN. The number of characters involved shall not exceed the remainder of the line. Supervisory information is not mandatory where recovery by NADIN is not required. The line shall end with CR LF (ASCII characters 0/13 and 0/10).

(3) Priority Indicator — The priority shall be indicated with two alphabetic characters, listed below from highest to lowest priority.

SS	Level 1
DD	Level 2
FF	Level 3
GG	Level 4
JJ	Level 4
KK	Level 4
LL	Level 4

FDEP messages will generally have a relatively low priority, due to the usually long (15 to 30 minutes) lead time between the messages and the events they describe. Allowances shall be made, however, to raise the priority when the lead time becomes significantly shorter.

(4) Addresses — Each address shall consist of a space and eight characters to identify each destination for the message. The end of each line of addresses shall be completed with CR LF. The last address shall be followed by File Separator (FS) CR LF. Address designators will be assigned by NADIN. Even

without NADIN, such addresses shall be included in order that the CCU can direct messages to the appropriate ports and the appropriate RCUs.

(5) Date Time Group — The date time group shall consist of six numerics indicating the day, hour, and minute (on a radio day basis) the message was prepared. The date time group is not mandatory where recovery by NADIN is not required.

(6) Message Originator — The originator of the message shall be identified with the eight-character address of the terminal location entering the message, followed by the optional data field and CR LF STX. NADIN will assign the address codes required.

(7) Optional Data Field — The optional data field shall be used to convey additional data of use to the users of the network and shall consist of one to three sub-fields of variable length. The field is delimited by space and CR LF STX and shall contain a maximum of 54 characters. Sub-fields may be used in any combination and shall be delimited as shown in Figure B-1. Sub-field A is for data of interest to the network and users, Sub-field B is of interest to the users, and Sub-field C is of interest to the network. Elements in any sub-field shall be optional and preceded by the element number and a hyphen. Each element shall be terminated with a period (ASCII character 2/14). Specific character assignments for these elements will be made by NADIN.

Sub-field A: Elements in this sub-field shall have the following meanings.

Element 1, Message Type — Three to eight characters for message formats not employing a message type as the first field in the message text, for text using a character or bit structure other than ASCII, or for duplicate messages. NADIN may insert a fixed message type based on message originator.

Element 2, Privacy — Not required for FDEP.

Element 3, Acknowledgement — One character to indicate the type of system acknowledgement required for the message. This shall

include generation of the necessary messages between NADIN and the message originator.

Element 4, Billing — One character to indicate the class of billing the message will be provided within NADIN; e.g., Class B, TELEX, reimbursable agreement. Message priority and message type will be used to determine billing class.

Element 5, Text Code and Format —Two characters to indicate the code and format of the text when the text is not in ASCII.

Element 6, Text Length — Not required for FDEP.

Sub-field B — Elements in this sub-field shall have the following meanings.

Element 1, Authentication Key — Not required for FDEP.

Element 2, Possible Duplicate Message — Three characters (PDM) shall be used to indicate a possible duplicate message when NADIN cannot logically determine absolute message accountability during recovery.

Element 3, File Number — ADP file number, as agreed by users.

Element 4, Data Sequence Number — Two characters shall be used to indicate messages submitted to NADIN which must be reassembled by the destination user to form a complete message. This number will be assigned by the originator, and NADIN will not be sensitive to it. The final number shall be followed immediately by the ASCII character F. This is only required for messages which are broken into blocks to meet the size limitation.

Sub-field C: Sub-field C may be used later for additional information which at the present is undefined.

B.2.4.2.3 Message Text

The message text shall consist of the information to be transferred (e.g., an FDEP message). The message text in any one message shall be limited by the originator such that the total message length (including heading and ending but excluding any insertions made by the channel control procedures) shall not exceed 250 characters. In those cases where the information to be transferred exceeds the allowable limit, the originator shall divide this information and form a sequence of messages, each with its own heading and ending and each within the allowable size limit. The Data Sequence Number (Optional Data Field, Subfield B, Element 4 of the heading) shall be used to identify the relative position of each message in the sequence for covenience in reassembling them at the destination.

B.2.4.2.4 Message Ending

The message ending shall consists of CR LF VT followed by the end-of-text character, ETX (ASCII 0/3).

B.3 NAS 9020/CONCENTRATOR INTERFACE

B.3.1. INTRODUCTION

B.3.1.1 Purpose

The information contained herein describes the interface control requirements for communications links between the NAS 9020 computer at each Air Route Traffic Control Center and the collocated FDIO control units. Both the Central Control Units (CCUs) and the Printer Control Units (PCUs) are considered.

To the degree pertinent, the procedures have been developed so as to be identical for both CCUs and PCUs. Further, they have been designed to be compatible with procedures specified for the interface between the NAS 9020 and the NADIN concentrator (which may functionally replace the CCU). Should the NADIN concentrator be used in place of the CCU, only those requirements presented below that are applicable to the NAS 9020/PCU interface shall apply.

B.3.1.2 Scope

This paper addresses interface control requirements at three levels:

- physical, i.e., the communications lines;
- link, i.e., the control of transmissions; and
- message, i.e., the actual data transmitted.

B.3.1.3 System Overview

The communications considered here are of two basic types: (1) output messages, i.e., transmissions from the NAS 9020 to terminals (printers) located either at remote FDEP sites or at the Center, and (2) input messages, i.e., transmissions from terminals (keyboards) at remote FDEP sites to the NAS 9020. Under the FDIO replacement program all such communications shall be routed through control units (concentrators) collocated with the

NAS 9020 at the Center. Output messages for the printers at the Center will be routed through PCUs; all other messages will be routed through CCUs.

The control units' functions involve both transmissions to and from the NAS 9020 and to and from the terminals. This paper is concerned only with the former. Pertinent functions related to output messages (for CCUs and PCUs) include:

- determination of output message acceptability and the initiation of recovery procedures when an unacceptable message is received;
- buffering of acceptable output messages for subsequent transmission to terminals; and
- conversion of output message text from EBCDIC to ASCII code.

Pertinent functions related to input messages (from CCUs only) include:

- conversion of input message text from ASCII to EBCDIC code;
- implementation of link control procedures for input messages;
- transmission of input messages to the NAS 9020; and
- implementation of recovery procedures when the NAS 9020 is down or otherwise not accepting input.

The functions of the NAS 9020 computer relative to such transmissions include:

- implementation of link control procedures for output messages;
- transmission of output messages;
- determination of input message acceptability and the initiation of recovery procedures when an unacceptable message is received; and

- implementation of recovery procedures when a control unit goes down.

Under the FDIO replacement program, the typical Center will contain two CCUs and four PCUs. One CCU and two PCUs are generally required for standard operations; the other units are included as one-on-one back-ups in case of equipment failure.

B.3.2 PHYSICAL CONTROL LEVEL

The physical connection between each control unit and the NAS 9020 computer shall be via cable through General Purpose Output (GPO) and/or General Purpose Input (GPI) ports in the Peripheral Adapter Module (PAM) of the computer. Each cable shall provide lines for bit-parallel, byte-serial transmission of EBCDIC code (7 data bits plus parity bit) and additional device control lines. Figures B-2 and B-3 identify the lines for the input and output links, respectively. Additional details on this interface are provided by IBM Form A27-2709-1 [11].

B.3.3 LINK CONTROL LEVEL

Link control shall be implemented by use of the control lines identified in Figures B-2 and B-3. These procedures are discussed below.

B.3.3.1 Input Transmissions (GPI/CCU Interface)

Whenever the NAS 9020 is able to receive transmission from the CCU, control line DC1 shall be raised by the PAM. DC1 shall not be dropped until such time as the computer cannot or will not accept transmissions from the CCU.

When the CCU has a message to transmit to the NAS 9020, it shall first determine if DC1 is up. If so, the CCU shall raise the I/O Request line and transmit one byte at a time in accordance with the procedures specified in IBM 9020 design data. The end of message shall be signaled by raising the EOM control line. Successive I/O request activations shall be separated in time by an interval greater than 25 microseconds.

B.3.3.2 Output Transmissions (GPO/CCU and GPO/PCU Interfaces)

The control units, by use of the Device Inoperative control line, shall inform the NAS 9020 of their status. If the control unit is available, the computer shall output pertinent messages as they are generated. The end of each message shall be signaled by raising the EOM control line.

B.3.3.3 Exception Recovery

Two types of situations may occur on these interfaces which disrupt standard operations — transmission errors and system failures. The system shall respond as follows to those conditions:

Transmission Errors — Transmission errors are detected as parity errors. If a control unit detects such an error in a byte of an output message, it shall raise the DS3 control line. The NAS 9020, upon sensing this, shall retransmit the byte. If the NAS 9020 detects a parity error in an input byte, it shall raise the DC3 control line. The CCU, upon sensing this, shall retransmit the byte.

System Failure — Generally, system failures will be detected through the control lines. Thus the loss of DC1 will indicate a computer failure and the activation of the Device Inoperative line will indicate a control unit failure. In addition, the computer and control units will maintain time-out functions. Detection of an intercharacter delay in excess of six milliseconds in received messages shall be interpreted as a failure in the transmitting device. When the NAS 9020 detects the failure of a control unit, it shall cause activation of the appropriate back-up control unit. When the CCU detects failure of the NAS 9020,it shall continue to accept input messages up to the capacity of the buffer. The CCU will then notify the remote units that it can not accept input (Receive Not Ready) until the NAS 9020 is again accepting input and the buffer load is reduced.

B.3.4. MESSAGE LEVEL

B.3.4.1 Code Set

All transmissions to and from the NAS 9020 computer shall use the EBCDIC code. It shall be the function of the CCU and PCUs to provide conversions to and from the IA-5 (ASCII) code used by all FDIO terminal equipment. Only those EBCDIC characters that can be converted to ASCII shall be used. Attachment B-1 identifies this set and indicates the appropriate conversions.

B.3.4.2 Message Format

The basic FDIO messages shall be embedded in a six-field message block. The field contents are indicated below:

Field	1	2	3	4	5	6
Output Messages	Priority	Space	Address	CR/LF	STX	Text
Input Messages	Date-Time Group	Space	Originator Address	CR/LF	STX	Text

Field 1 — The first field shall be used to indicate message priority for output messages and the date-time group for input messages. Priority shall be designated by a two-character code as follows:

GG, for lower priority messages, such as delay, arrival, or cancellation;

FF, for all other FDIO messages.

The date-time group shall be six numerics indicating the day, hour, and minute (DDHHMM, on a radio day basis).

Field 2 -- The second field shall always be a single space character used as a delimiter.

Field 3 — The third field shall contain the address of the remote station orginating an input message or the address(es) of the remote station(s) designated to receive an output message. Individual addresses shall consist of 8 characters. Multiple addresses shall be used only for output messages and shall be separated by single space characters. The total field shall not exceed 67 characters including the spaces.

Field 4 — The fourth field shall contain two characters — carriage return (CR) and line feed (LF) —used as a delimiter.

Field 5 — The fifth field shall contain the start of text character, STX (HEX 02), indicating that the text follows.

Field 6 — The last field shall contain only the basic FDIO message. (End of message is indicated via the EOM control line.)

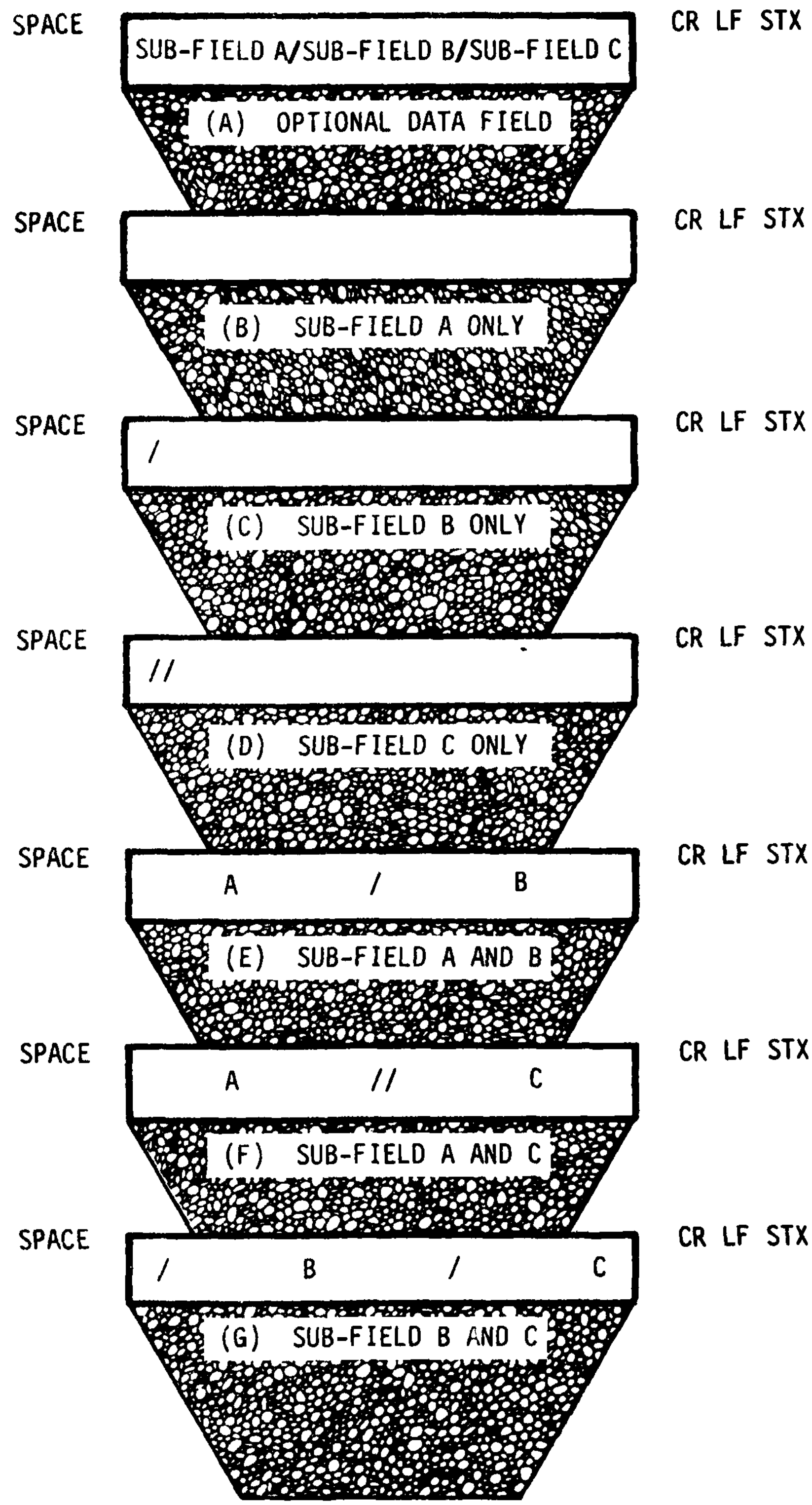


FIGURE B-1: OPTIONAL DATA FIELD -- SUB-FIELD DELIMITERS

DATA LINES (9)	SIGNAL INITIATED BY
PARITY BIT	CCU
BIT POSITION 0	CCU
BIT POSITION 1	CCU
BIT POSITION 2	CCU
BIT POSITION 3	CCU
BIT POSITION 4	CCU
BIT POSITION 5	CCU
BIT POSITION 6	CCU
BIT POSITION 7	CCU

CONTROL LINES (6)	
I/O REQUEST	CCU
ADAPTER RESPONSE	PAM
DEVICE CONTROL LINE 1 (DC1)	PAM
DC3	PAM
DC4	PAM
END OF MESSAGE (EOM)	CCU

FIGURE B-2: GPI/CCU PHYSICAL INTERFACE

DATA LINES (9)	SIGNAL INITIATED BY
PARITY BIT	PAM
BIT POSITION 0	PAM
BIT POSITION 1	PAM
BIT POSITION 2	PAM
BIT POSITION 3	PAM
BIT POSITION 4	PAM
BIT POSITION 5	PAM
BIT POSITION 6	PAM
BIT POSITION 7	PAM

CONTROL LINES (6)	
I/O REQUEST	CCU/PCU
ADAPTER RESPONSE	PAM
DEVICE INOPERATIVE	CCU/PCU
DEVICE STATUS LINE 3 (DS3)	CCU/PCU
DS5	CCU/PCU
DS6	CCU/PCU
DS7	CCU/PCU
ADAPTER SELECTED	PAM
END OF MESSAGE (EOM)	PAM

FIGURE B-3: CONTROL UNIT/GPO PHYSICAL INTERFACE

ATTACHMENT B-1

EBCDIC/ASCII CONVERSION

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
NUL	00	00	NUL/IDLE
SOH	01	01	START OF HEADING
STX	02	02	START OF TEXT
ETX	03	03	END OF TEXT
EOT	37	04	END OF TRANSMISSION
ENQ	2D	05	ENQUIRY
ACK	2E	06	ACKNOWLEDGE
BEL	2F	07	AUDIBLE OR ATTENTION SIGNAL
BS	16	08	BACKSPACE
HT	05	09	HORIZONTAL TABULATION
LF	25	0A	LINE FEED
VT	0B	0B	VERTICAL TABULATION
FF	0C	0C	FORM FEED
CR	0D	0D	CARRIAGE RETURN
SO	0E	0E	SHIFT OUT
SI	0F	0F	SHIFT IN
DLE	10	10	DATA LINK ESCAPE
DC1	11	11	DEVICE CONTROL 1
DC2	12	12	DEVICE CONTROL 2

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
DC3	13	13	DEVICE CONTROL 3
DC4	3C	14	DEVICE CONTROL 4
NAK	3D	15	NEGATIVE ACKNOWLEDGE
SYN	32	16	SYNCHRONOUS IDLE
ETE	26	17	END OF TRANSMISSION BLOCK
CAN	18	18	CANCEL
EM	19	19	END OF MEDIUM
SUB	3F	1A	SUBSTITUTE
ESC	27	1B	ESCAPE
FS	1C	1C	FILE SEPARATOR
GS	1D	1D	GROUP SEPARATOR
RS	1E	1E	RECORD SEPARATOR
US	1F	1F	UNIT SEPARATOR
SP	40	20	SPACE
!	4F	21	EXCLAMATION MARK
"	7F	22	QUOTATION MARK
#	7B	23	NUMBER
$	5B	24	DOLLAR
%	6C	25	PERCENT
&	50	26	AMPERSAND
'	7D	27	APOSTROPHE
(	4D	28	OPEN PARENTHESES

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
)	5D	29	CLOSE PARENTHESES
*	5C	2A	ASTERISK
+	4E	2B	PLUS
,	6B	2C	COMMA
-	60	2D	HYPHEN
.	4B	2E	PERIOD
/	61	2F	SLANT
Ø	FØ	3Ø	ZERO
1	F1	31	ONE
2	F2	32	TWO
3	F3	33	THREE
4	F4	34	FOUR
5	F5	35	FIVE
6	F6	36	SIX
7	F7	37	SEVEN
8	F8	38	EIGHT
9	F9	39	NINE
:	7A	3A	COLON
;	5E	3B	SEMICOLON
<	4C	3C	LESS THAN
=	7E	3D	EQUAL
>	6E	3E	GREATER THAN

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
?	6F	3F	QUESTION MARK
@	7C	40	AT
A	C1	41	UPPER CASE ALPHABETICS
B	C2	42	
C	C3	43	
D	C4	44	
E	C5	45	
F	C6	46	
G	C7	47	
H	C8	48	
I	C9	49	
J	D1	4A	
K	D2	4B	
L	D3	4C	
M	D4	4D	
N	D5	4E	
O	D6	4F	
P	D7	50	
Q	D8	51	
R	D9	52	
S	E2	53	
T	E3	54	
U	E4	55	

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
V	E5	56	
W	E6	57	
X	E7	58	
Y	E8	59	
Z	E9	5A	
[	4A	5B	OPEN BRACKET
\	EØ	5C	REVERSE SLANT
]	5A	5D	CLOSED BRACKET
∧	5F	5E	CIRCUMFLEX
—	6D	5F	UNDERLINE
`	79	6Ø	GRAVE ACCENT
a	81	61	LOWER-CASE ALPHABETICS
b	82	62	
c	83	63	
d	84	64	
e	85	65	
f	86	66	
g	87	67	
h	88	68	
i	89	69	
j	91	6A	
k	92	6B	
l	93	6C	

SYMBOLIC NAME	HEX REPRESENTATION EBCDIC	ASCII	MEANING
m	94	6D	
n	95	6E	
o	96	6F	
p	97	7Ø	
q	98	71	
r	99	72	
s	A2	73	
t	A3	74	
u	A4	75	
v	A5	76	
w	A6	77	
x	A7	78	
y	A8	79	
z	A9	7A	
{	6Ø	7B	OPEN BRACE
|	6A	7C	VERTICAL LINE
}	DØ	7D	CLOSE BRACE
—	A1	7E	OVERLINE
DEL	Ø7	7F	DELETE

BIT POSITIONS

0	1	2	3	4	5	6	7	EBCDIC
	7	6	5	4	3	2	1	ASCII

APPENDIX C

THROUGHPUT DELAY ANALYSIS

C.1 PURPOSE AND SCOPE

This appendix presents a model for estimating delays associated with FDEP messages transmitted between RCUs and a CCU (or NADIN concentrator). The analysis considers message transmissions on a full duplex, multipoint line. The delays analyzed are those between the time a message enters the sending control unit's buffer and the time it enters the receiving control unit's buffer.

C.2 SYSTEM OPERATIONS OVERVIEW

The communications link being analyzed is a 4-wire (full duplex), leased multipoint line, operating under the ADCCP link protocol with the CCU designated the primary station. The key features of such operations are presented in the following subsections.

C.2.1 Transmissions

All transmissions between RCUs and the CCU will be in units called frames. For purposes of this analysis, a frame can be classified as either:

- an information frame, containing a message for the computer or a remote terminal; or

- a link control frame, used solely to transmit a link control command or response.

Most link control frames will consist of six octets (i.e., six 8-bit characters). An information frame will consist of six octets plus a variable length message field.

Since the system employs full duplex transmissions, frames can be transmitted in both directions simultaneously. Only one RCU can transmit at a time, however.

C.2.2 Output Line

The pair of wires used to transmit frames from the CCU to RCUs will be referred to as the output line. It is useful to group the transmissions on this line into four categories:

- output messages with polls, i.e., information frames which indicate to the receiving RCU that it may (and should) now use the input line;
- output messages without polls, i.e., other information frames;
- supervisory polls, i.e., link control frames which indicate to the receiving RCU that it may (and should) now use the input line; and
- miscellaneous link control frames.

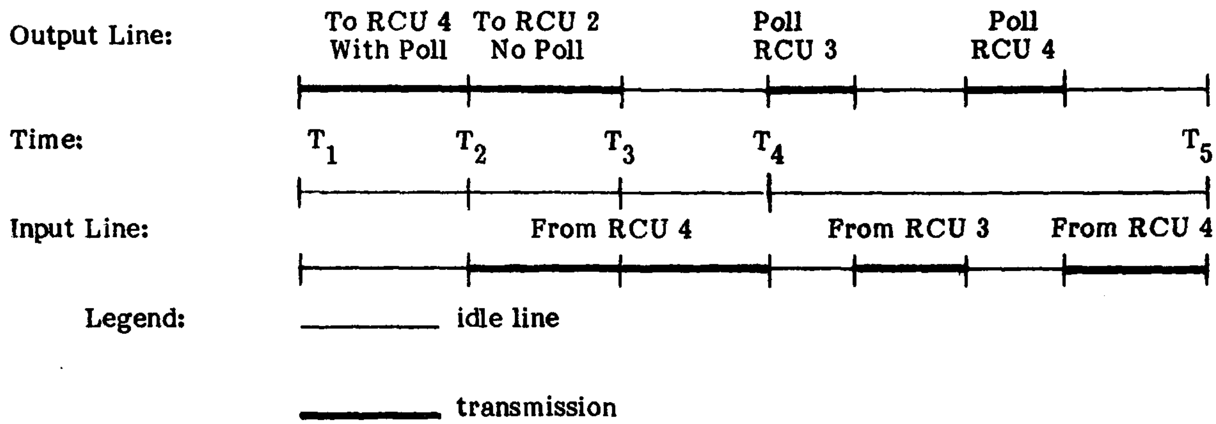
The CCU will transmit a polling frame at each opportunity. Such an opportunity exists any time except for the interval between the transmission of one poll and the receipt of the response to that poll. Thus, although the CCU can transmit an information frame at any time, it will include a poll in the frame only if it is not awaiting or receiving the response to a previous poll. When there are no output messages to transmit, the CCU will conduct cyclical polling, i.e., it will transmit supervisory polls to the RCUs on the line, sequentially. Such polls are separated in time only by the delay for responses. The cyclical polling will be interrupted whenever an output message enters the CCU output buffer.

C.2.2 Input Line

The pair of wires used to transmit frames from RCUs to the CCU will be referred to as the input line. Only one RCU can transmit at a time. This is controlled by the polling from the CCU, with each RCU transmitting only in response to its being polled. The response to a poll may be one or more information frames or a link control frame; there must, however, always be a response at the earliest opportunity.

C.2.4 Transmission Sequence

The diagram below represents a typical transmission sequence:



In this example, the CCU has a two-message output queue at time T_1, one message for RCU 4 and one for RCU 2. No other output messages enter the buffer between T_1 and T_5. At T_1 the message to RCU 4 is transmitted with the poll bit set. When this transmission is completed, time T_2, the message for RCU 2 is transmitted immediately, but without a poll. Also at T_2, RCU 4 initiates its response. With no more output messages to transmit after T_3, the CCU is ready to initiate cyclical polling. The CCU must wait, however, until the input line is idle, i.e. at time T_4. It is assumed here that cyclical polling had previously been interrupted after RCU 2 had been polled, hence polling is reinitiated with RCU 3. Note that although RCU 4 had just been polled as part of an information frame transmission, it retains its order in the cyclical polling. In this way the busier RCUs will be polled more often.

C.2.5 Acknowledgements

Acceptable receipt of information frames must be acknowledged. This is generally accomplished as part of (the control field of) the next return transmission. Thus in the above example, RCU 4 should acknowledge the receipt of the message from the CCU (between T_1 and T_2) as part of its message transmission (between T_2 and T_4). The CCU will acknowledge receipt of that message as part of the subsequent polling of RCU 4.

On occasion it will not be practical to wait for the next "return transmission." This might occur if there are already seven information frames unacknowledged by a single

receiving station. In such cases a link control frame can be used to request acknowledgement.

C.3 APPROACH

This analysis applies standard queueing theory to the processing of the frames. Each control unit is considered a single server system, with the messages (customers) arriving according to a Poisson distribution and with processing times described by an exponential distribution.

The major difficulty presented by this approach is that, unlike standard queueing situations, message processing at the RCUs is interrupted between successive messages, while the CCU polls and processes other RCUs. Standard queueing theory can still be applied, however, by considering such interruptions as part of each input message's (extended) servicing time.

C.3.1 Queueing Assumptions and Approximations

(1) Input and output message arrival (i.e., their entry to the transmission buffers) at each control unit can be characterized by the Poisson distribution.

(2) The actual service time for a message will include (a) processing at the transmitting station, (b) transmission, (c) propagation delay, and (d) processing at the receiving station. For convenience, this actual service time will be referred to simply as transmission time.

(3) The extended servicing time for an input message is defined as the inverse of the processing rate, i.e., the actual servicing time plus delays while the RCU is waiting to be polled. For input messages in a queue, this will be the time between the completion of transmission for successive messages at the particular RCU. For messages which arrive when there is no queue, this will be the time between message arrival and the completion of that message's transmission. It will be assumed that the mean extended service time is exponentially distributed.

C.3.2 Other Assumptions and Approximations

(1) No message transmitted to or from the CCU will require more than one frame (250 characters in the information field).

(2) Each RCU will transmit one and only one frame in response to a single poll; this may be either an information or link control frame.

(3) The line capacity used for exception recovery and link control activities, other than polling, is negligible.

(4) There is essentially no difference in the distribution of transmission times for input and output messages.

C.4 ANALYSIS

This analysis is directed toward development of algorithms for calculating:

W_0 — the mean delay between output message arrival in the CCU's transmission buffer and its acceptance into the RCU's receiving buffer, during the peak operations hour.

$W_I(J)$ — the mean delay between input message arrival in RCU J's transmission buffer and its acceptance into the CCU's receiving buffer, during the peak operations hour.

The parameters whose values are assumed known for this analysis are:

NRS — the number of RCUs on the multipoint line.

NMI(J) — the number of input messages to be transmitted from RCU J to the CCU during the peak hour.

NMO(J) — the number of output messages to be transmitted from the CCU to RCU J during the peak hour.

TXI — the mean time required to transmit one information frame in either direction (including processing time, transmission time, and propagation delay).

TXC — the mean time required to transmit one link control frame in either direction.

NMIT = $\sum_J NMI(J)$ — the total number of input messages transmitted to the CCU during the peak hour.

NMOT = $\sum_J NMO(J)$ — the total number of output messages transmitted by the CCU during the peak hour.

It will be convenient in subsequent discussions to use the following substitutions for the indicated combination of the "known" parameters:

KOI	=	NMOT x TXI/3600
KII	=	NMIT x TXI/3600
KOC	=	NMOT x TXC/3600
KIC	=	NMIT x TXC/3600
KO	=	1 + KOC - KOI
KI	=	1 + KIC - KII

C.4.1 Output Delay Time

The output line operates as a standard queueing process in so far as output information frames are concerned. The first message to arrive is transmitted immediately; subsequent messages are queued and transmitted as soon as all preceding message transmissions are completed. Thus:

$$W_0 = 1/(M_0 - L_0); \quad \text{for } M_0 > L_0$$

where

M_0 is the mean output message service rate, in messages per unit time,

and

L_0 is the mean output message arrival rate, in messages per unit time.

From the above definitions:

$$M_0 = 1/TXI$$

$$L_0 = NMOT/3600$$

Should $L_0 \geq M_0$, W_0 is not defined, i.e., delays will continue to increase with time since the system would be saturated. This condition is unlikely to occur in the system considered here.

Thus:

$$W_0 = 1/\left[(1/TXI) - (NMOT/3600)\right]$$

$$= TXI/\left[1 - (NMOT \times TXI/3600)\right]$$

and, from the earlier definitions:

$$W_0 = TXI/(1\text{-}KOI)$$

C.4.2 Input Delay Time

Message input from each RCU is also treated as a standard queueing process, with (extended) service times defined to include polling delays. Thus:

$$W_I(J) = 1/\left[M_I(J) - L_I(J)\right]$$

for $M_I(J) > L_I(J)$

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COMMUNICATIONS SUPPORT FOR FLIGHT DATA ENTRY AND PRINTOUT TERMI--ETC(U)
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UNCLASSIFIED NAC/FR-303B/01 FAA-RD-80-96 NL

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where

$L_I(J)$ is the mean arrival rate of input messages at RCU J,

and

$M_I(J)$ is the mean servicing rate of input messages at RCU J.

From earlier definitions:

$$L_I(J) = NMI(J)/3600.$$

Assuming the service time to be exponentially distributed:

$$M_I(J) = 1/T_S(J)$$

where

$T_S(J)$ is the mean extended service time for input messages from RCU J.

As suggested earlier, the extended service time for an input message from RCU J consists of two parts — the polling delay (i.e., the delay while other RCUs are being processed) and the processing time for RCU J. Thus:

$$T_s(J) = CYC(J) + TXI$$

where

CYC(J) is the mean polling delay for RCU J.

Thus:

$$M_I(J) = 1/(CYC(J) + TXI)$$

It thus remains only to determine CYC(J).

C.4.3 Polling Delay

The polling delay, CYC(J), was defined differently for inut messages that encounter a queue and those that encounter none. When there is a queue, the polling delay includes the time to process all RCUs that are polled between successive pollings of RCU J. When there is no queue, the delay includes only the time to process the RCUs that are polled between the message's arrival at RCU J and the next polling of RCU J.

Despite this difference, it has been shown* that, if the time between successive polls of RCU J is exponentially distributed (as assumed here), the mean delays for the two situations will be equal. Thus CYC(J) will be determined by considering only the case where the message encounters a queue.

The polling delay, CYC(J), can be determined from:

$$\text{CYC(J)} = \text{S(J)} \times 3600/\text{NP}$$

where

S(J) is the mean number of times the CCU polls other RCUs between successive polls of RCU J;

and

NP is the total number of polls transmitted by the CCU during the peak hour (and hence 3600/NP is the mean time between successive polls).

Two types of polls must be considered, those included in information frames and those that are included in link control frames (as part of cyclical polling). Thus:

$$\text{NP} = \text{NPI} + \text{NPC}$$

---

*For example, see Kleinrock [12], Chapter 5.

where

NPI is the number transmitted as part of information frames;

and

NPC is the number transmitted as part of link control frames.

The polls directed to RCU J can similarly be divided. Those that are part of information frames will be proportional to the number of output frames transmitted to station J, i.e.:

$$NPIR(J) = NPI \times NMO(J)/NMOT$$

where

NPIR(J) = is the mean number of polls directed to RCU J in information frames.

Those that are part of the cyclical polling will be uniformly distributed over all RCUs, thus:

$$NPCR = NPC/NRS$$

where

NPCR is the mean number of polls directed to each RCU through cyclical polling.

The ratio of NP to the total number of polls directed to RCU J is the mean number of polls transmitted per poll of RCU J. Thus:

$$S(J) = \left[NP/(NPIR(J) + NPCR)\right] - 1$$

In order to determine the numbers of polls transmitted, it should be recalled that (1) polls can only be transmitted when the input line is idle and (2) RCUs will transmit only in response to polls. Thus, if there are NP polls and NMIT input information frames

transmitted (assumed earlier to be transmitted on a one-per-poll basis), there must also be NP-NMIT link control frames transmitted on the input line. Thus

$$\text{FIU} = (\text{NMIT} \times \text{TXI} + (\text{NP-NMIT}) \times \text{TXC})/3600$$

where

FIU is the fraction of the peak hour that the input line is in use.

Using the substitutions defined earlier:

$$\text{FIU} = \text{KII} - \text{KIC} + \text{NP} \times \text{TXC}/3600$$

Assuming random overlap of input line usage with information frame transmission on the output line:

$$\text{NPI} = \text{NMOT} \times (1\text{-FIU})$$

$$= \text{NMOT} \times (\text{KI} - \text{NP} \times \text{TXC}/3600)$$

Cyclical polling can only be conducted when the input line is idle and there are no output messages to transmit. The fraction of the hour that the output line is used for information frames is given by:

$$\text{NMOT} \times \text{TXI}/3600 = \text{KOI}$$

Since the responses to cyclical polling were included in FIU, the fraction of the hour available for cyclical polling will be:

$$(1\text{-FIU}) \times (1\text{-KOI})$$

and the expected number of cyclical polls will be:

$$\text{NPC} = 3600 \times (1\text{-FIU}) \times (1\text{-KOI})/\text{TXC}$$

At this point it remains only to determine NP in terms of the known parameters. This is accomplished using:

$$NP = NPI + NPC$$

$$= NMOT \times (1-FIU) + 3600 \times (1-FIU) \times (1-KOI)/TXC$$

$$= (1-FIU) \times (NMOT + 3600 \times (1-KOI)/TXC)$$

$$= (KI - NP \times TXC/3600) \times (3600 \times KOC/TXC + 3600\ (1-KOI)/TXC)$$

Solving for NP yields:

$$NP = 3600 \times KI/\left[TXC \times (1 + 1/KO)\right]$$

C.4.4 Calculation Summary

In order to calculate $W_I(J)$ using the earlier specified parameters, the following steps can be used:

(1) Determine:

$$\begin{aligned}
KOI &= NMOT \times TXI/3600 \\
KOC &= NMOT \times TXC/3600 \\
KII &= NMIT \times TXI/3600 \\
KIC &= NMIT \times TXC/3600 \\
KO &= 1 + KOC - KOI \\
KI &= 1 + KIC - KII
\end{aligned}$$

(2) Determine the polling cycle factors:

$$\begin{aligned}
NP &= 3600 \times KI/\left[TXC \times (1 + 1/KO)\right] \\
NPI &= NMOT \times (KI - NP \times TXC/3600) \\
NPC &= NP - NPI \\
NPCR &= NPC/NRS
\end{aligned}$$

(3) For each RCU (J) of interest determine:

$$NPIR(J) = NPI \times NMO(J)/NMOT$$

$$S(J) = \left[NP/(NPIR(J) + NPCR)\right] - 1$$

$$CYC(J) = S(J) \times 3600/NP$$

$$L_I(J) = NMI\ (J)/3600$$

$$M_I(J) = 1/(CYC(J) + TXI)$$

$$W_I(J) = 1/\left[M_I(J) - L_I(J)\right]$$

APPENDIX D

LINE LAYOUT ANALYSIS

D.1 PURPOSE AND SCOPE

This appendix presents the detailed results of the line layout analysis. The circuits defining three near-optimal layouts and the associated communications costs are presented for each FDEP system.

D.2 ORGANIZATION

The bulk of this appendix consists of 20, two-page forms showing the results of the line layout analysis. Each form applies to a single FDEP system; i.e., all special FDEP sites associated with a single ARTCC. These forms are ordered alphabetically by the name of the metropolitan area (major city) in or near which the ARTCC is located.

The first page for each system shows the number of individual circuits and the costs associated with the three line layouts generated—based on maximum circuit size constraints of 7, 5, and 3 RCUs per circuit. The second page shows the individual circuits for each of the three layouts.

The circuits within each layout have been arbitrarily numbered. Each circuit is defined by the location of the remote drops and the manner in which those locations are connected. The symbolic names used to identify the locations are, with one exception, the standard three-character codes used for airports and other FAA and military aviation facilities (these are identified in Appendix A). The one exception is the New York City Common IFR Room (N90). Since it is projected that two RCUs will be required for that facility, it is necessary to consider it as two distinct sites. These have been arbitrarily designated N901 and N902.

The connections suggested by GRINDER for each circuit are indicated by "Remote Drop" numbers. Thus the line is assumed to run from the ARTCC to Remote Drop 1, then to Remote Drop 2, etc. Branches are indicated by vertical connecting lines. Thus:

```
GSP ┬ CLT — INT — GSO
    └ AVL ┬ TRI
          └ TYS
```

indicates a single circuit with seven RCUs, none of which is more than four links away from the center. At GSP the circuit branches—one branch going to CLT, the other to AVL. At AVL it again branches—one branch going to TRI and the other to TYS. Three or more branches from a single site are also possible.

RESULTS OF LINE LAYOUT ANALYSIS FOR:

ALBUQUERQUE ARTCC (ZAB)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	3	4
PRIMARY SERVICE COST:	$1032.08	$1032.08	$1196.83
BACK-UP SERVICE COST:	367.20	367.20	297.60
TOTAL COST:	$1399.28	$1399.28	$1494.43

RESULTS OF LINE LAYOUT FOR: ALBUQUERQUE ARTCC (ZAB)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	ABQ —	AMA					
2	ROW —	ELP					
3	DMA —	TUS —	P90 —	PHX			

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	ABQ —	AMA					
2	ROW —	ELP					
3	DMA —	TUS —	P90 —	PHX			

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	ABQ —	AMA					
2	ROW —	ELP					
3	PHX —	P90					
4	DMA —	TUS					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

ATLANTA ARTCC (ZTL)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	4	6
PRIMARY SERVICE COST:	$1399.08	$1496.82	$1666.25
BACK-UP SERVICE COST:	1039.20	970.80	746.40
TOTAL COST:	$2438.28	$2467.62	$2412.65

RESULTS OF LINE LAYOUT FOR: ATLANTA ARTCC (ZTL)

CIRCUIT SIZE CONSTRAINT 7 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	MCN —	WRB —	CSG —	MXF —	MGM —	BHM	
2	ATL —	FTY —	PDK —	CHA			
3	GSP —	CLT —	INT —	GSO			
		AVL —	TRI				
			TYS				

CIRCUIT SIZE CONSTRAINT 5 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	CSG —	MXF —	MGM —	BHM			
2	ATL —	FTY —	MCN —	WRB			
3	PDK —	CHA —	TYS —	AVL —	TRI		
4	GSP —	CLT —	INT —	GSO			

CIRCUIT SIZE CONSTRAINT 3 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	MGM —	MXF					
		BHM					
2	ATL —	FTY					
3	MCN —	WRB —	CSG				
4	GSP —	AVL —	TRI				
5	CLT —	INT —	GSO				
6	PDK —	CHA —	TYS				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

BOSTON ARTCC (ZBW)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	4	4	6
PRIMARY SERVICE COST:	$1242.69	$1265.81	$1404.58
BACK-UP SERVICE COST:	895.20	793.20	637.20
TOTAL COST:	$2137.89	$2059.01	$2041.78

RESULTS OF LINE LAYOUT FOR: BOSTON ARTCC (ZBW)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	BED	BOS	PVD	NCO			
				FMH			
2	BTV						
3	ORH	BDL	ALB	UCA	RME	SYR	
4	MHT	PWM	BGR				

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	ORH	PVD	NCO				
			FMH				
2	BTV						
3	BDL	ALB	UCA	RME	SYR		
4	MHT	PWM	BGR				
		BED	BOS				

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	PVD	NCO					
		FMH					
2	BTV						
3	UCA	RME	SYR				
4	ORH	BDL	ALB				
5	MHT	PWM	BGR				
6	BED	BOS					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

CHICAGO ARTCC (ZAU)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	4	6
PRIMARY SERVICE COST:	$1403.22	$1460.74	$1627.44
BACK-UP SERVICE COST:	1005.60	866.40	764.40
TOTAL COST:	$2408.82	$2327.14	$2391.84

RESULTS OF LINE LAYOUT FOR: CHICAGO ARTCC (ZAU)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	ORD	PWK	MKE	GRB			
2	MDW	SBN	FWA				
			AZO	GRR	MKG		
3	RFD	MSN					
		MLI	CID	ALO			
			PIA	CMI			

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	ORD	PWK	MKE	GRB			
		MDW					
2	SBN	FWA					
		AZO	GRR	MKG			
3	RFD	MSN					
4	PIA	MLI	CID	ALO			
		CMI					

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	PWK	MKE	GRB				
2	AZO	GRR	MKG				
3	MDW	SBN	FWA				
4	ORD	RFD	MSN				
5	PIA	CMI					
6	MLI	CID	ALO				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

CLEVELAND ARTCC (ZOB)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	4	5	8
PRIMARY SERVICE COST:	$1661.88	$1720.68	$1974.72
BACK-UP SERVICE COST:	1302.00	1234.80	958.80
TOTAL COST:	$2963.88	$2955.48	$2933.52

RESULTS OF LINE LAYOUT FOR: CLEVELAND ARTCC (ZOB)

CIRCUIT SIZE CONSTRAINT 7 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	MFD	CAK	YNG	PIT	AGC	CKB	
2	TOL	DET					
3	BKL	ERI	BUF	ROC			
		CGF		IAG			
		CLE					
4	DTW	YIP	JXN	LAN			
		PTK	FNT	MBS			

CIRCUIT SIZE CONSTRAINT 5 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	CAK	YNG	PIT	AGC	CKB		
2	CGF	CLE					
		MFD					
3	BKL	ERI	BUF	ROC			
				IAG			
4	TOL	YIP	JXN	LAN			
			DTW				
5	DET	PTK	FNT	MBS			

CIRCUIT SIZE CONSTRAINT 3 RCUs

REMOTE DROPS

Circuit No.	1	2	3	4	5	6	7
1	PIT	AGC	CKB				
2	CAK	YNG	ERI				
3	MFB						
4	BKL	CGF					
		CLE					
5	BUF	ROC					
		IAG					
6	YIP	JXN	LAN				
7	PTK	FNT	MBS				
8	TOL	DTW	DET				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

DENVER ARTCC (ZDV)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	2	3	3
PRIMARY SERVICE COST:	$ 831.22	$ 859.54	$ 890.30
BACK-UP SERVICE COST:	402.00	367.20	350.40
TOTAL COST:	$1233.22	$1226.74	$1240.70

RESULTS OF LINE LAYOUT FOR: DENVER ARTCC (ZDV)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	GJT	FMN					
2	DEN	ARA	COS	PUB			
		CYS	CPR				

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	CYS	CPR					
2	GJT	FMN					
3	DEN	ARA	COS	PUB			

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	DEN	CYS	CPR				
2	GJT	FMN					
3	ARA	COS	PUB				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

FORT WORTH ARTCC (ZFW)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	4	4	7
PRIMARY SERVICE COST:	$1652.29	$1661.62	$2055.79
BACK-UP SERVICE COST:	1152.00	1016.40	757.20
TOTAL COST:	$2804.29	$2678.02	$2812.99

RESULTS OF LINE LAYOUT FOR: FORT WORTH ARTCC (ZFW)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	ACT						
2	DYS	ABI	SJT	MAF	LBB		
3	TIK	OKC	PWA	CSM			
		TUL					
4	DFW	DAL	TYR	BAD	SHV	MLU	
						TXK	

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	DYS	ABI	SJT	MAF	LBB		
2	DFW	DAL	ACT				
3	TIK	OKC	PWA	CSM			
		TUL					
4	TYR	BAD	SHV	MLU			
				TXK			

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	DAL	TYR	TXK				
2	SJT	MAF	LBB				
3	DFW	ACT					
4	ABI	DYS					
5	TIK	OKC	PWA				
6	CSM	TUL					
7	SHV	BAD					
		MLU					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

HOUSTON ARTCC (ZHU)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	4	6
PRIMARY SERVICE COST:	$1467.21	$1603.57	$1855.64
BACK-UP SERVICE COST:	1240.80	936.00	746.40
TOTAL COST:	$2708.01	$2539.57	$2602.04

RESULTS OF LINE LAYOUT FOR: HOUSTON ARTCC (ZHU)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	IAH	BPT					
		HOU					
2	CLL	BSM	AUS	SAT	CRP	MFE	BRO
3	LCH	LFT	BTR	MSY	NEW	GPT	MOB

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	CRP	MFE	BRO				
2	CLL	BSM	AUS	SAT			
3	BTR	MSY	NEW	GPT	MOB		
4	IAH	BPT	LCH	LFT			
		HOU					

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	HOU	CLL					
2	CRP	MFE	BRO				
3	IAH	BPT	LCH				
4	AUS	BSM					
		SAT					
5	NEW	GPT	MOB				
6	LFT	BTR	MSY				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

INDIANAPOLIS ARTCC (ZID)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	2	3	5
PRIMARY SERVICE COST:	$1163.19	$1226.76	$1374.18
BACK-UP SERVICE COST:	832.80	729.60	626.40
TOTAL COST:	$1995.99	$1956.36	$2000.58

RESULTS OF LINE LAYOUT FOR: INDIANAPOLIS ARTCC (ZID)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	CVG	LUK					
		LEX	HTS	CRW			
			SDF	EVV			
2	IND	MIE	DAY	CMH	OSU		
		LAF	HUF				

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	CVG	LUK					
		LEX	HTS	CRW			
2	MIE	DAY	CMH	OSU			
3	IND	SDF	EVV				
		LAF	HUF				

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	LEX	HTS	CRW				
2	DAY	CMH	OSU				
3	IND	SDF	EVV				
4	MIE	LUK	CVG				
5	LAF	HUF					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

JACKSONVILLE ARTCC (ZJX)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	3	5
PRIMARY SERVICE COST:	$1277.45	$1277.45	$1488.82
BACK-UP SERVICE COST:	769.20	769.20	562.80
TOTAL COST:	$2046.65	$2046.65	$2051.62

RESULTS OF LINE LAYOUT FOR: JACKSONVILLE ARTCC (ZJX)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	SAV —	CHS —	FLO —	CAE —	AGS		
2	TLH —	ABY —	DHN —	PFN —	PNS		
3	JAX —	GNV —	DAB				

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	SAV —	CHS —	FLO —	CAE —	AGS		
2	TLH —	ABY —	DHN —	PFN —	PNS		
3	JAX —	GNV —	DAB				

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	AGS —	CAE —	FLO				
2	SAV —	CHS					
3	TLH —	ABY					
4	DHN —	PFN —	PNS				
5	JAX —	GNV —	DAB				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

KANSAS CITY ARTCC (ZKC)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	4	5
PRIMARY SERVICE COST:	$1395.76	$1498.15	$1595.00
BACK-UP SERVICE COST:	997.20	775.20	690.00
TOTAL COST:	$2392.96	$2273.35	$2285.00

RESULTS OF LINE LAYOUT FOR: KANSAS CITY ARTCC (ZKC)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	JLN —	SGF —	MWA				
2	COU —	SUS —	STL —	ALN —	SPI —	DEC	
3	MKC —	MCI —	STJ —	SLN —	HUT —	ICT	

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	JLN —	SGF —	MWA				
2	SUS —	STL —	ALN —	SPI —	DEC		
3	MKC —	MCI —	STJ				
		COU					
4	SLN —	HUT —	ICT				

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	JLN —	SGF —	MWA				
2	SUS —	STL —	ALN				
3	MKC —	MCI —	STJ				
4	SLN —	HUT —	ICT				
5	COU —	SPI —	DEC				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

LOS ANGELES ARTCC (ZLA)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	5	5	7
PRIMARY SERVICE COST:	$1338.43	$1340.74	$1448.69
BACK-UP SERVICE COST:	1152.00	948.00	793.20
TOTAL COST:	$2490.43	$2288.74	$2241.89

RESULTS OF LINE LAYOUT FOR: LOS ANGELES ARTCC (ZLA)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	040	ONT					
2	SMO						
3	LGB	FUL	SNA	NZJ	CRQ	NKX	SAN
4	LAX	BUR	EDW	BFL			
			VNY	OXR	SBA		
5	LAS						

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	LGB	FUL	ONT	040			
2	NZJ	SNA					
		CRQ	NKX	SAN			
3	SMO	VNY	OXR	SBA			
4	LAX	BUR	EDW	BFL			
5	LAS						

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	LGB	ONT	040				
2	FUL	SNA	NZJ				
3	CRQ	NKX	SAN				
4	VNY	OXR	SBA				
5	BUR	EDW	BFL				
6	LAX	SMO					
7	LAS						

RESULTS OF LINE LAYOUT ANALYSIS FOR:

MEMPHIS ARTCC (ZME)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	3	5
PRIMARY SERVICE COST:	$1337.94	$1337.94	$1499.37
BACK-UP SERVICE COST:	786.00	752.40	562.80
TOTAL COST:	$2123.94	$2090.34	$2062.17

RESULTS OF LINE LAYOUT FOR: MEMPHIS ARTCC (ZME)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	GLH —	JAN —	NMM —	HSV			
2	CGI —	PAH —	BNA				
3	MEM —	PBF —	LIT —	HOT —	FSM —	FYV	

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	GLH —	JAN —	NMM —	HSV			
2	MEM —	CGI —	PAH —	BNA			
3	PBF —	LIT —	HOT —	FSM —	FYV		

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	MEM —	HSV					
2	GLH —	JAN —	NMM				
3	CGI —	PAH —	BNA				
4	PBF —	LIT					
5	HOT —	FSM —	FYV				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

MIAMI ARTCC (ZMA)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	3	5
PRIMARY SERVICE COST:	$ 901.64	$ 901.64	$1051.81
BACK-UP SERVICE COST:	540.00	540.00	453.60
TOTAL COST:	$1441.64	$1441.64	$1505.41

RESULTS OF LINE LAYOUT FOR: MIAMI ARTCC (ZMA)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	FMY —	SRQ —	TPA —	PIE			
2	MLB —	MCO —	ORL				
3	MIA —	TNT					
	—	FLL —	PBI				

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	FMY —	SRQ —	TPA —	PIE			
2	MLB —	MCO —	ORL				
3	MIA —	TNT					
	—	FLL —	PBI				

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	SRQ —	TPA —	PIE				
2	MLB —	MCO —	ORL				
3	MIA —	TNT					
4	FMY						
5	FLL —	PBI					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

MINNEAPOLIS ARTCC (ZMP)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	4	6
PRIMARY SERVICE COST:	$1499.77	$1653.25	$1801.56
BACK-UP SERVICE COST:	830.40	711.60	573.60
TOTAL COST:	$2330.17	$2364.85	$2375.16

RESULTS OF LINE LAYOUT FOR: MINNEAPOLIS ARTCC (ZMP)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	FAR	GFK					
		BIS					
2	FSD	SUX	OFF	OMA	LNK	GRI	
					DSM		
3	MSP	DLH					
		RST	LSE				

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	FSD						
2	FAR	GFK					
		BIS					
3	SUX	OFF	OMA	LNK	GRI		
4	MSP	DLH					
		RST	LSE				
			DSM				

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	FSD						
2	FAR	GFK					
		BIS					
3	DSM	OMA	OFF				
4	SUX	LNK	GRI				
5	RST	LSE					
6	MSP	DLH					

RESULTS OF LINE LAYOUT ANALYSIS FOR:

NEW YORK ARTCC (ZNY)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	4	5	8
PRIMARY SERVICE COST:	\$1512.00	\$1579.02	\$1846.97
BACK-UP SERVICE COST:	1376.40	1137.60	913.20
TOTAL COST:	\$2888.40	\$2716.62	\$2760.17

RESULTS OF LINE LAYOUT FOR: NEW YORK ARTCC (ZNY)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	TEB	EWR	TTN	PNE	PHL	ILG	
					ACY		
2	ABE	RDG	MDT	CXY			
3	ISP	HPN	LGA	N901	N902		
					JFK		
4	AVP	BGM	ELM	IPT			

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	TTN	PNE	PHL	ILG			
			ACY				
2	ABE	RDG	MDT	CXY			
3	N901	N902					
		JFK					
4	AVP	BGM	ELM	IPT			
5	ISP	HPN	TEB	EWR			
				LGA			

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	PNE	PHL	ILG				
2	RDG	MDT	CXY				
3	TTN	ABE	AVP				
4	ISP	HPN					
5	N901	N902					
		JFK					
6	BGM	ELM	IPT				
7	LGA	TEB	EWR				
8	ACY						

RESULTS OF LINE LAYOUT ANALYSIS FOR:

OAKLAND ARTCC (ZOA)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	4	4	5
PRIMARY SERVICE COST:	$ 925.75	$ 932.93	$ 988.30
BACK-UP SERVICE COST:	625.20	505.20	435.60
TOTAL COST:	$1550.95	$1438.13	$1423.90

RESULTS OF LINE LAYOUT FOR: OAKLAND ARTCC (ZOA)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	RNO						
2	SJC	MRY					
3	090	OAK	SFO				
			SCK	SAC	MCC	SMF	
4	FAT						

CIRCUIT SIZE CONSTRAINT 5 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	RNO						
2	SCK	SAC	MCC	SMF			
3	OAK	090					
		SFO					
		SJC	MRY				
4	FAT						

CIRCUIT SIZE CONSTRAINT 3 RCUs

Circuit No.	REMOTE DROPS 1	2	3	4	5	6	7
1	RNO						
2	SJC	MRY					
		SCK					
3	SAC	MCC	SMF				
4	OAK	090					
		SFO					
5	FAT						

RESULTS OF LINE LAYOUT ANALYSIS FOR:

SALT LAKE CITY ARTCC (ZLC)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	3	3	4
PRIMARY SERVICE COST:	$ 946.71	$ 946.71	$1112.87
BACK-UP SERVICE COST:	259.20	259.20	206.40
TOTAL COST:	$1205.91	$1205.91	$1319.27

RESULTS OF LINE LAYOUT FOR: SALT LAKE CITY ARTCC (ZLC)

CIRCUIT SIZE CONSTRAINT 7 RCUs

Circuit No.	1	2	3	4	5	6	7
1	SLC						
2	BIL —	HLN	GFA MSO				
3	BOI						

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	SLC						
2	BIL —	HLN	GFA MSO				
3	BOI						

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	SLC						
2	HLN	GFA MSO					
3	BIL						
4	BOI						

RESULTS OF LINE LAYOUT ANALYSIS FOR:

SEATTLE ARTCC (ZSE)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	2	3	5
PRIMARY SERVICE COST:	$1066.00	$1148.97	$1239.51
BACK-UP SERVICE COST:	770.40	649.20	580.80
TOTAL COST:	$1836.40	$1798.17	$1820.31

RESULTS OF LINE LAYOUT FOR: SEATTLE ARTCC (ZSE)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	YKM	MWH	SKA	GEG			
			PSC	PDT			
2	TCM	PDX	EUG	MFR			
		SEA	BFI	PAE			

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	MWH	SKA	GEG				
		PSC	PDT				
2	SEA	BFI	PAE				
3	TCM	YKM					
		PDX	EUG	MFR			

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	TCM						
2	MWH	SKA	GEG				
3	SEA	BFI	PAE				
4	YKM	PSC	PDT				
5	PDX	EUG	MFR				

RESULTS OF LINE LAYOUT ANALYSIS FOR:

WASHINGTON ARTCC (ZDC)

CIRCUIT SIZE CONSTRAINT (RCUs):	7	5	3
CIRCUITS GENERATED:	2	3	5
PRIMARY SERVICE COST:	$ 974.54	$1025.35	$1184.57
BACK-UP SERVICE COST:	723.60	620.40	517.20
TOTAL COST:	$1698.14	$1645.75	$1701.77

RESULTS OF LINE LAYOUT FOR: WASHINGTON ARTCC (ZDC)

CIRCUIT SIZE CONSTRAINT 7 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	LYH	ROA					
		RDU	FAY	ILM			
2	IAD	DCA	ADW	BWI			
			RIC	PHF	ORF		

CIRCUIT SIZE CONSTRAINT 5 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	IAD	RIC	PHF	ORF			
2	LYH	ROA					
		RDU	FAY	ILM			
3	DCA	ADW	BWI				

CIRCUIT SIZE CONSTRAINT 3 RCUs

	REMOTE DROPS						
Circuit No.	1	2	3	4	5	6	7
1	RIC	PHF	ORF				
2	RDU	FAY	ILM				
3	LYH	ROA					
4	IAD						
5	DCA	ADW	BWI				

APPENDIX E

GLOSSARY OF TERMS AND ABBREVIATIONS

ADCCP — Advanced Data Communications Control Procedure, a standardized bit-oriented link level communications protocol.

ANK — alphanumeric keyboard, FDEP terminal equipment currently used to enter messages from remote sites.

ARTCC — Air Route Traffic Control Center, an FAA facility which provides en route control of the air routes over a major portion of the U.S.; each of the 23 ARTCCs contains an NAS 9020 computer and is scheduled to contain a NADIN concentrator.

ASCII — American Standard Code for Information Interchange, the code used by FDIO replacement equipment.

ARTS — Automated Radar Terminal System, a system of terminal area radars that have a direct communications connection with the NAS 9020s.

Availability — the probability that a service or piece of equipment is operational at a time when it is supposed to be operating.

Bit — a binary digit, generally considered to take either the value of 0 or 1.

Byte — a unit of digital data, generally made up of a series of 8 bits.

Center — same as ARTCC.

CCU — Central Control Unit, a microprocessor included in the FDIO specifications, that would be located at each ARTCC to interface lines from remote FDEP sites with the NAS 9020 computer.

Concentrator — a piece of telecommunications equipment, usually a small computer, used to consolidate transmissions from several separate input lines onto a single output line and to separate transmissions from a single input line onto appropriate output lines.

CRT — cathode ray tube (display), FDEP terminal equipment included in FDIO specifications to serve as message forming displays (for RANKs) where space permits.

DCCU — Data Communications Control Unit, the equipment currently used to interface remote FDEP terminals with the NAS 9020; at least one is located at each remote FDEP site.

Drops — termination points on a multipoint line.

Duplex — telecommunications links that allow transmission in two directions (also see full and half duplex).

EBCDIC — Extended Binary Coded Decimal Interchange Code, the code used by the NAS 9020 computer.

FDEP — Flight Data Entry and Printout, an FAA communications service used to transmit flight-plan-related messages between remote facilities (TRACONs, towers, etc.) and the NAS 9020 computers.

FDEP System — the equipment and communications links associated with FDEP service in the area controlled by a single ARTCC.

FDIO — Flight Data Input and Output, an FAA program designed to replace equipment for and generally upgrade FDEP and related services.

FSAS — Flight Service Automation System, an FAA program designed to upgrade the dissemination of flight service data.

FSP — Flight Strip Printer, FDEP terminal equipment currently used to display messages received at the remote sites from the NAS 9020 computer. (FSPs are also used at ARTCCs by en route controllers).

FSPCU — Flight Strip Printer Control Unit, the equipment currently used to interface FSPs at ARTCCs with the NAS 9020; one is required for each FSP.

Full Duplex — telecommunications links that allow simultaneous transmission in two directions.

GPI — general purpose input adaptor ports, ports for the NAS 9020 PAM that can be used for a variety of input lines.

GPO — general purpose output adaptor ports, ports for the NAS 9020 PAM that can be used for a variety of output lines.

GRINDER — a proprietary package of interactive computer programs developed by NAC to facilitate the design and analysis of data communications networks.

Half Duplex — telecommunications links that allow transmissions in two directions, but in only one direction at a time.

Hex — Hexidecimal, a numbering system using 16 digits, generally represented by the decimal digits 0 to 9 and the alphabetic characters A to F.

Modem — modulator/demodulator, a piece of telecommunications equipment that superimposes intelligence onto a modulated carrier output signal and extracts intelligence from such an input signal.

Multipoint or Multidrop — a communications link that connects one termination point to several others on a single circuit.

NAS 9020 — The computer system used to process flight data at each ARTCC.

NADIN — National Airspace Data Interchange Network, an FAA program to provide a common backbone network for various current and future FAA data communications services.

Overhead — those transmissions or portions of transmissions that are not part of the basic information being exchanged; generally this includes control signals or information needed to administer the communications link or direct message processing.

PAM — peripheral adapter module, that portion of the NAS 9020 computer that provides interface adaptors for input/output lines.

PCU — Printer Control Unit, a microprocessor included in the FDIO specifications, that would be located at ARTCCs to interface collocated RFSPs with the NAS 9020 computer.

Point-to-Point — a communications link that connects two (and only two) termination points.

PT&T — Perforated Tape and Telegram code, the code currently used by FDEP equipment.

RANK -- replacement alphanumeric keyboards, terminal equipment included in the FDIO specifications to replace ANKs at the remote FDEP sites.

RCU — Remote Control unit, a microprocessor included in the FDIO specifications, that would be located at remote sites to interface local terminals with the CCUs (it would replace DCCUs).

RFSP — replacement flight strip printers, terminal equipment included in the FDIO specifications to replace FSPs at remote FDEP sites and at the ARTCCs.

STAGE III — a terminal area control radar service for providing IFR separation to non-IFR flights.

APPENDIX F

REFERENCES

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